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16. Abstract

The traditional modeling process was developed in response to the need to evaluate future transportation needs in large, rapidly growing urban areas. The process is an excellent tool for evaluation of land-use/transportation alternatives. However, it is generally recognized that such a system level must be refined for project-level applications. A case study showed that the manual procedure followed by the Texas Corridor Analysis Group produced results which were different from the traffic assignments results using the TRANPLAN microcomputer package. A new alternative procedure for performing corridor analysis is proposed. This procedure is illustrated through a case study.

A capacity restraint procedure which equalizes the V/C ratio of groups of links which constitute competing routes was developed and tested. The prototype model demonstrated that the V/C ratios of the links in each group converge toward the average V/C for that group. Counted volumes for turning movements were not available. Therefore, the assigned turning movements utilizing the equalized link V/C ratio method were compared to the results using the incremental capacity restraint procedure. The equalized link V/C procedure was judged to produce turning movements which are more realistic than the present capacity restraint method.

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# TRAFFIC FORECASTING FOR PROJECT DEVELOPMENT

Research Report 1112-1F

by

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Research Study Number 2-10-87-1112

Sponsored by
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Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

November 1989

# METRIC (SI*) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

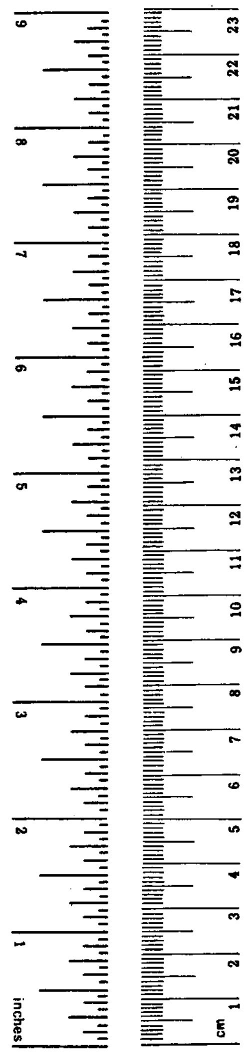
| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 2.54 | millimetres | mm |
| ft | feet | 0.3048 | metres | m |
| yd | yards | 0.914 | metres | m |
| mi | miles | 1.61 | kilometres | km |
| | | **AREA** | | |
| in² | square inches | 645.2 | millimetres squared | mm² |
| ft² | square feet | 0.0929 | metres squared | m² |
| yd² | square yards | 0.836 | metres squared | m² |
| mi² | square miles | 2.59 | kilometres squared | km² |
| ac | acres | 0.395 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams | Mg |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | millilitres | mL |
| gal | gallons | 3.785 | litres | L |
| ft³ | cubic feet | 0.0328 | metres cubed | m³ |
| yd³ | cubic yards | 0.0765 | metres cubed | m³ |

NOTE: Volumes greater than 1000 L shall be shown in m³.

### TEMPERATURE (exact)

| | | | | |
|---|---|---|---|---|
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

* SI is the symbol for the International System of Measurements




## APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimetres | 0.039 | inches | in |
| m | metres | 3.28 | feet | ft |
| m | metres | 1.09 | yards | yd |
| km | kilometres | 0.621 | miles | mi |
| | | **AREA** | | |
| mm² | millimetres squared | 0.0016 | square inches | in² |
| m² | metres squared | 10.764 | square feet | ft² |
| km² | kilometres squared | 0.39 | square miles | mi² |
| ha | hectores (10 000 m²) | 2.53 | acres | ac |
| | | **MASS (weight)** | | |
| g | grams | 0.0353 | ounces | oz |
| kg | kilograms | 2.205 | pounds | lb |
| Mg | megagrams (1 000 kg) | 1.103 | short tons | T |
| | | **VOLUME** | | |
| mL | millilitres | 0.034 | fluid ounces | fl oz |
| L | litres | 0.264 | gallons | gal |
| m³ | metres cubed | 35.315 | cubic feet | ft³ |
| m³ | metres cubed | 1.308 | cubic yards | yd³ |

### TEMPERATURE (exact)

| | | | | |
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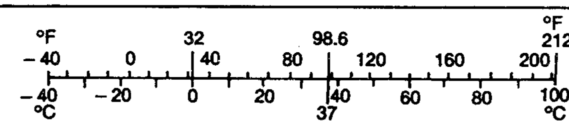
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |




These factors conform to the requirement of FHWA Order 5190.1A.

**ABSTRACT**

The traditional modeling process was developed in response to the need to evaluate future transportation needs in large rapidly growing urban areas. The process is an excellent tool for evaluation of land-use/transportation alternatives. However, it is generally recognized that such a system level must be refined for project-level applications. This research reviewed and evaluated procedures for the refinement of traffic assignment results for applications to project planning. This review included the procedures included in NCHRP Report 255 and the corridor analysis procedure used by the Texas State Department of Highways and Public Transportation (SDHPT) Corridor Analysis Group. A case study showed that the manual procedure followed by SDHPT Corridor Analysis Group produced results which were quite different from the traffic assignment results using the TRANPLAN microcomputer package. A new alternative procedure for performing corridor analysis is proposed. This procedure was illustrated through a case study.

A capacity restraint procedure which equalizes the v/c ratio of groups of links which constitute competing routes was developed and tested. The prototype model demonstrated that the v/c ratios of the links in each group converge toward the average v/c ratio for that group. Counted volumes for turn movements were not available for use in evaluating the assignment results. Therefore, the assigned turn movements utilizing the equalized link v/c ratio method were compared to the results using the incremental capacity restraint procedure contained in the TRANPLAN package. The equalized link v/c procedure was judged to produce turn movements which are more realistic than the present capacity restraint method.

## SUMMARY

This report contains the results of a study concerned with the development of traffic forecasts for project-level analysis. A case study using US-290 in Austin, Texas, compared the results using the subarea analysis procedures of the TRANPLAN microcomputer package and the Texas Travel Demand Package for a mainframe computer. Both packages produced similar results. This case study also compared the TRANPLAN results with the results using the Texas State Department of Highways Group. None of the procedures tested produced results which matched those of the Corridor Analysis Group procedures.

An alternative corridor analysis procedure was developed and evaluated using State Highway 161 as a case study; the results were compared to these using the Corridor Analysis Group procedures. The difference between the turning movements of the alternative iterative procedure and the Corridor Analysis Group procedure averaged less than 30%. The iterative turning movement procedure eliminated the problem of "zero" volumes.

A theoretical procedure for estimating turning movements as a percentage of approach volume was developed. The theoretical results were compared to actual turn percentages using count data from the Sherman-Denison, Texas, urban area. The count data were for the 9-hour period 7:00 a.m. to 10:00 a.m., 11:00 a.m. to 2:00 p.m., and 3:00 p.m. to 6:00 p.m. Comparison of the theoretical and observed turn percentages indicates that the procedure may be applicable to high volume intersections.

A prototype model equalizing the volume-to-capacity (V/C) ratios of links which comprise competing routes was developed and evaluated using the Tyler, Texas, study area network. The procedure produced the expected results in that the link V/C ratios converged toward the average V/C ratio for the link group. Within the project-level analysis area, the equalized link V/C ratio method produced "better" results than the present incremental restraint assignment procedure. The results were judged to be "better" because there were fewer zero movements; the distribution of left turns, thru movements,

and right turns was also improved. The incremental method was found to produce better results than the other restraint assignment procedures on the Tyler network. Therefore, by implication, the equalized link V/C ratio procedure produces assignment results which are better than the existing restraint assignment methods.

## IMPLEMENTATION

Further evaluation of the alternative corridor analysis procedure should be undertaken prior to its adoption for routine application.

Prior to implementation of the equalized link V/C ratio restraint assignment procedure, the two following enhancements are needed:

(1) Increase in the number of link groups on which the V/C ratios are equalized, and

(2) Programming to improve and increase the information which the user can easily access for analysis. Further evaluation using a large network is also suggested.

## DISCLAIMER

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# CHAPTER I. INTRODUCTION

The modeling process utilized in urban transportation studies was developed in response to the need to evaluate future transportation needs in large rapidly growing urban areas. This computerized modeling procedure is effective for system-level analyses involving the evaluation of land-use/transportation alternatives, the compatibility of given land-use and transportation scenarios, the identification of travel corridors and the approximate volume of future traffic in each corridor, and staging of major transportation system improvements in response to projected urban growth. Thus, the traditional transportation modeling process has been found to be an excellent tool for system-level analysis and policy evaluation.

The modeling process is also applicable to statewide and large regional studies. Further, it has been successfully used in a variety of other applications such as the Texas Airport System Study (1).

The desire to analyze portions of a large urban region in greater detail than the system-level analysis allows has lead to subarea studies. Thus, windowing and subarea focusing procedures were developed to allow the analyst to make changes in the land-use and/or the transportation system within the subarea of interest. These procedures permit the analysis of localized alternatives within the subarea while maintaining the regional context in which the subarea is situated. It also minimizes the data set which must be manipulated, and it substantially reduces the computer time needed. Each windowing and subarea focusing technique has been incorporated in the Texas Travel Demand Package as well as various other computer packages. Through Study No. 2-10-87-1110, "Subarea Analysis Using Microcomputers," procedures and software were developed so that the subarea analysis could be performed on a microcomputer and interfaced with the Texas Travel Demand Package on the SDHPT mainframe computer. While using greater network detail than the system-level studies, the subarea analysis utilizes the same trip generation and trip distribution models.

The models used in the Texas Travel Demand Model (as well as other mainframe packages such as UTPS and the various microcomputer packages such as TRANPLAN, MicroTRIPS and MINUTP) involve a variety of simplifying assumptions. These assumptions are necessitated by the complex combination of a large number of factors involved in individual travel behavior. Consequently, estimates of base-year traffic on individual facilities in a system-level analysis can differ significantly from the actual counts. This may be the case even when it is recognized that one- or two-day short counts produce average daily traffic (ADT) estimates which may have about an 80% probability of being within ± 15% of the true ADT (2). Where there are multiple facilities within a corridor, the error in the total corridor volume will be much less due to the offsetting errors on the individual facilities. Furthermore, the precision necessary in system-level analysis is the difference in the capacity of 2 vs. 4 vs. 6 vs. 8 lanes or about 15,000 for an arterial street and about 40,000 for a freeway.

**THE PROBLEM**

More detailed uses and needs for traffic forecasts involve project-level applications including the following:

1. Design of route-segments (including ramps, interchanges, and intersections) which are maintained by the SDHPT. These "on-system" roadways consist of all the freeways and many of the major at-grade streets within urban areas, the majority of which are the urban extensions of state highways and farm/ranch-to-market roads.
2. Design of major street segments other than those facilities on the SDHPT-maintained system (e.g., the off-system facilities). These off-system facilities are a municipal or county responsibility. They interconnect with the on-system roadways and are, therefore, of some interest to SDHPT.
3. Site traffic impact studies for proposed urban development projects which may range from a few dwelling units to mixed use development consisting of several million square feet. Such projects range in size from small to large. Large projects will influence intersections some distance from the site. Also, large projects are likely to be located with access to on-system facilities.
4. Site access and circulation design of proposed urban development projects; including drive-through length and width, curb return radii, channelization,

and future traffic control. Commercial and industrial developments and larger residential subdivisions are likely to have access to an on-system roadway. Such projects range in size from small to large.

5. Intersection design; including number of lanes, number and length of left-turn bays, length of right-turn bays, curb return radii, channelization, and future traffic control.
6. Expected speed, delay, queue length.
7. Effect of proposed changes in land use.
8. Effect of multiple closely spaced access drives as opposed to fewer better designed access points.
9. Geometric design for large trucks.
10. Pavement design.

The application identified in the item 1 above, design of on-system facilities, is of obvious concern to SDHPT. Site traffic generation and site access and circulation design are of major concern to municipalities, and in states other than Texas, to counties as well as to the developers of the projects. However, there is an increasing concern for these applications in those SDHPT districts which contain expanding urban areas. This concern comes from the recognition that traffic generated by urban development impacts the on-system facilities, even though the development may not directly front or have direct access to an SDHPT-maintained facility.

When a large traffic generating project is involved, the area of influence will be considerable and will impact intersections and interchanges which are some distance from the site. The location and design of the access will directly impact the adjacent public street, especially nearby intersections and/or interchanges. Therefore, the SDHPT interest in project-level applications extends beyond the design of on system facilities.

Irrespective of the user, the first eight project-level applications share a common problem. That is, the need for detailed traffic projections which provide individual movements (i.e, left, right, and thru movements at intersections) by time of day.

Design for large trucks, the item 10 above, can be categorized into three situations: (1) "site-specific" development such as truck terminals and industrial areas; (2) truck routes through towns and cities; and (3) freeway and street design in general.

## SYSTEM-LEVEL VERSUS PROJECT-LEVEL ANALYSIS

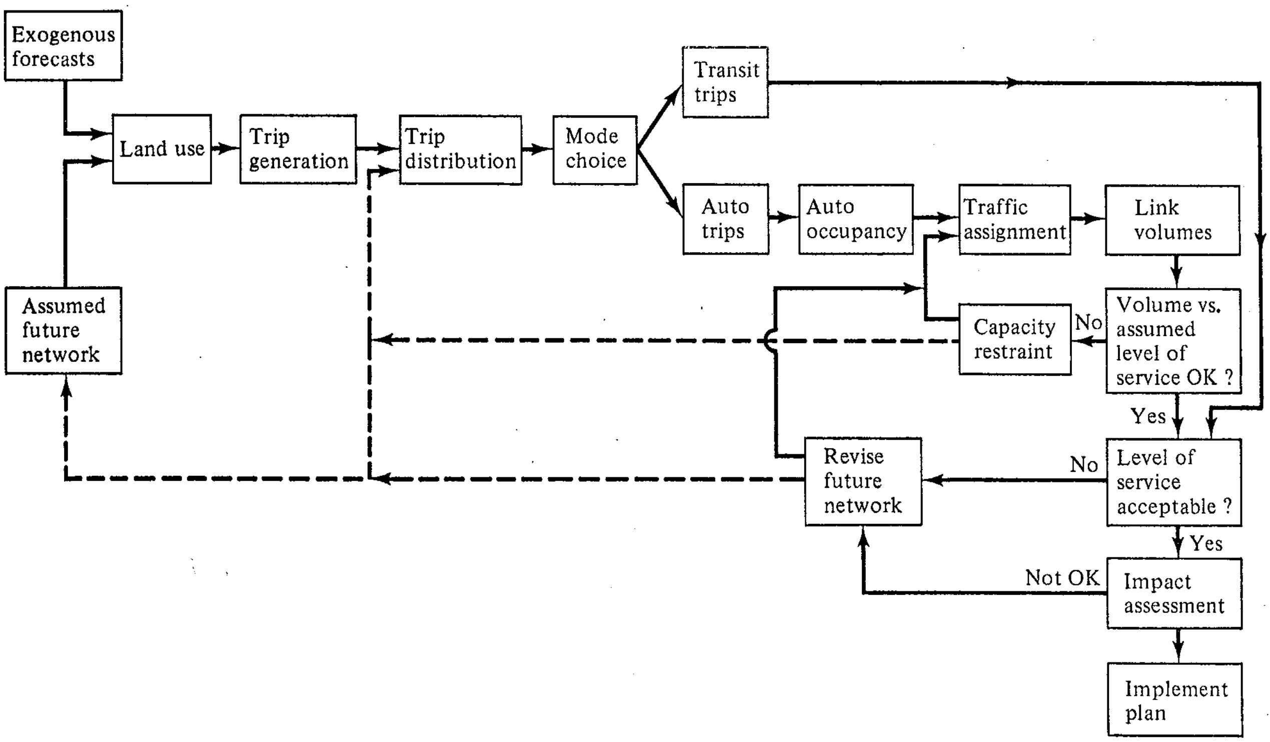
A simplified flow chart of the traditional urban transportation planning process is given in Figure 1. As previously indicated this process was developed to evaluate future land-use/transportation alternatives. The process is also an excellent tool for the following:

1. Identifying major travel corridors and the approximate future traffic volume within each corridor given a future land-use arrangement.
2. Identifying potential major problems in a proposed network given a future land use or evaluating a proposed land-use arrangement given a future transportation network.
3. Providing a basis for planning and programming major transportation network improvements.

The process provides information (mean trip length and trip length frequency) by which the compatibility of the proposed land-use plan and the proposed transportation plan can be evaluated. It can also be used to evaluate the relative accessibility of the existing land-use/transportation pattern, to identify changes in accessibility that would result with different transportation systems, and to see if proposed large commercial or industrial concentrations are situated at locations which have, or will have, a high level of accessibility.

The urban transportation modeling process, which relies heavily upon computer models, is a macroscopic tool which uses an abstract computerized representation of the street and highway network in the traffic assignment. The results are not directly suitable at the microscopic or site planning level because it does not provide

1. Reliable forecasts of turning movements at individual intersections or access drives;
2. Time of day projections of the traffic volumes on individual street segments;
3. Reliable forecasts of traffic volumes at access drives for different access locations and/or designs;
4. The effect of numerous access points to an arterial as opposed to only a few direct access points;




Source: Reference (3)

**FIGURE 1 Simplified Flow Chart of the Urban Transportation Planning Process.**

5. Effects of minor changes in land use;
6. Effects of modest changes in the location of activities; e.g., the positioning of 250,000 square feet of retail floor area on each of the 4 quadrants of an intersection versus the location of all 1 million square feet in one quadrant; and
7. Reliable forecasts of the traffic on the frontage roads separate from that or the main lanes of a freeway or at-grade arterial.

Both the urban general (comprehensive) planning process and the urban transportation planning process commonly utilize a single 20-year time horizon. In order to deal more effectively with transportation and land-use development, there is growing recognition that the planning process should be stratified into the following four planning horizons or level:

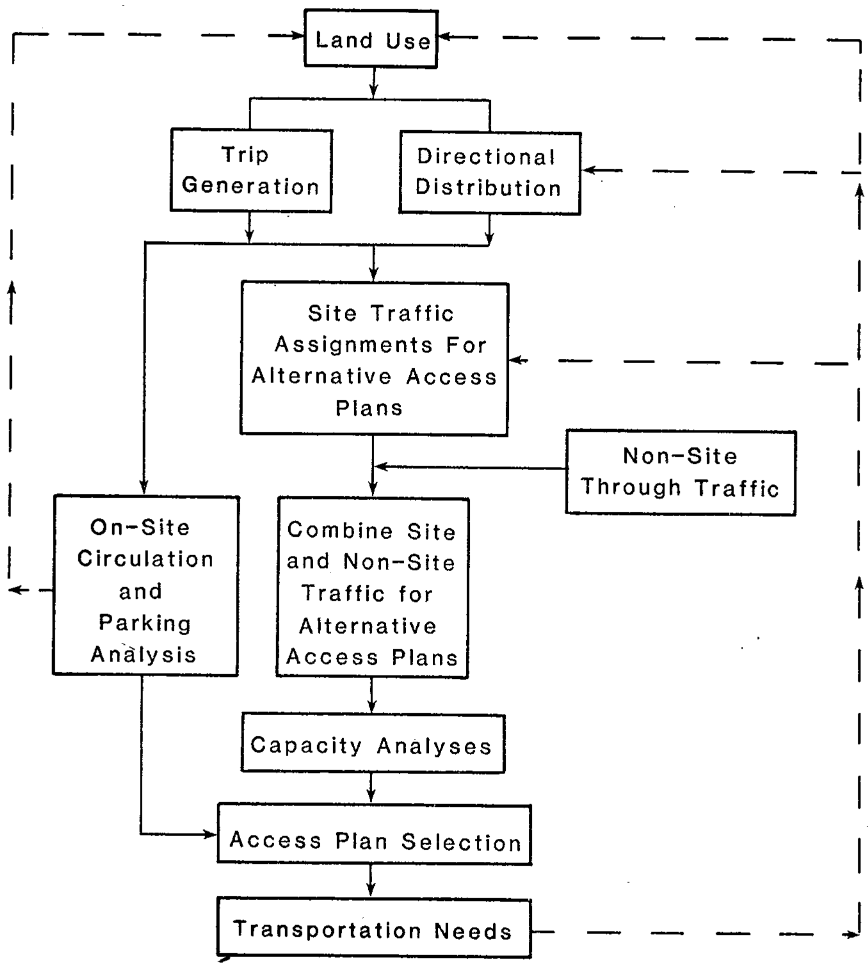
1. Level 1: An infinite, or at least a very long, horizon for strategic planning of major transportation corridors and other permanent elements of the urban environment.
2. Level 2: A long-range horizon (20 years) for the planning of significant changes in transportation facilities, water, waste water, and other major infrastructure elements and land-use patterns.
3. Level 3: A medium-range horizon (3 to 5 years and 10 years for very large capital improvement projects) for planning, programming, and design of major development.
4. Level 4: A short-range horizon (commonly one year) for the approval of individual construction contracts for public improvements and private development projects.

The successive stages should constitute a progression of planning design with an increasing degree of refinement and detail at each successive stage.

The Level 1 and 2 plans should provide general policy guidance for public and private development decisions. These are the shortest time horizons for which direct application of the urban transportation modeling process was intended. Level 3 needs to provide effective coordination of public sector infrastructure decisions and coordination between the public sector and private sector development decisions. Level 4 deals with the funding of individual construction contracts.

Site planning is essentially a Level 3 activity. It involves analysis of the traffic impact of specific proposed development, the adequacy of the access drives, and the suitability of the on-site circulation and parking. Such analyses are site-specific and microscale. Consequently, different analytical procedures are involved. A general framework for site-specific analysis is diagrammed in Figure 2 (3).

Much of the terminology used in urban transportation planning and in site project planning is similar. However, the applications and uses are very different, as indicated in Table 1. The site-specific nature of traffic analyses of individual proposed development projects requires more detailed methods and techniques than those which are suitable for the evaluation of land-use/transportation alternatives, which is the objective of the urban transportation study.




Source: Reference (3)

**FIGURE 2 Site-Traffic Analysis.**

TABLE 1 COMPARISON OF THE TRADITIONAL URBAN TRANSPORTATION STUDY AND THE SITE PLAN AND TRAFFIC ANALYSIS

| *Analysis Element* | *Urban Transportation Planning Study* | *Site Plan and Traffic Analysis* |
|---|---|---|
| | Interzonal and intrazonal trips generally are obtained with gravity model using zone-to-zone, and intrazonal travel times obtained by trip generation. | commonly used trip-generation rates are auto trips.<br><br>Trips are projected by direction: into the development (destination) or out from the development (origin).<br><br>When a large development is mixed-use (e.g., retail and office), the number of trips to and from the site must be adjusted. |
| Mode choice | Person trips are "split" into auto and transit—generally using some mathematical model. The auto mode trips are then converted to auto/vehicle trips using auto occupancy factors. In urban areas where there is little or no transit, auto/vehicle trips and transit trips (if any) are most appropriately obtained by direct generation. | Where some of the trips are expected to be made by transit, the number of transit trips is projected and the number of auto trips is reduced using auto occupancy rates. |
| Trip distribution | Zone-to-zone movements obtained using a gravity model calibrated for the urban area. | Percentage of traffic to/from the site obtained by: (1) geographical distribution of clientele within the primary trade zones—manual analysis using judgment, or (2) gravity model application—computerized or manual methods, or (3) analogy—appropriate in situations where a similar business is already located in close proximity to the proposed development. |
| Traffic assignment | Zone-to-zone trips assigned to the coded, abstract network using minimum paths, all-or-nothing, or multiple-path "capacity" restrained assignment. | Percentage of traffic using each access point is projected. Traffic volume at each access point by movement. Traffic added by the proposed development projected by movement for each street segment and intersection adjacent to and within the traffic influence area of the proposed development. If computerized, thorough, detailed analysis of the results is essential. |
| Use of results | Assess the internal consistency of a land use–transportation plan.<br><br>Evaluate and compare mutually exclusive land use–transportation plans.<br><br>Identify major problem areas in the transportation plan given a land use plan.<br><br>Identify movement corridors and project the approximate volume within each corridor.<br><br>Identify major system deficiencies in the existing transportation system in comparison to the adopted land use–transportation plan. | Identify the selected peak-hour demands at individual access points of a proposed development.<br><br>Assess the capacity of the proposed access and its adequacy to accommodate the projected demand.<br><br>Evaluate the layout of the on-site circulation and parking, building location, and location and design of the access in relation to the adjacent street(s).<br><br>Identify the need for street improvements such as additional through lanes, turn lanes, and traffic control adjacent to and within the area of traffic influence of the proposed development. |

Source: Reference (3)

## DESIGN ACCURACY

It is common practice to estimate the average annual daily traffic (AADT) or average annual weekday traffic (AWDT) from traffic counts which are made for a short time (one or two days). These short counts provide estimates which are within about 10% or 15% of the actual AADT or AWDT with about 80% confidence. It is not logical to interpret traffic assignment forecasts as having greater accuracy than the precision with which existing traffic is counted.

Moreover, when interpreting traffic application, it is important to note that volume is, essentially, a continuous variable (traffic volume can be measured in increments of one vehicle). Capacity, on the other hand, can be provided only in large increments, i.e., one lane per approach. Figure 3 illustrates the maximum theoretical capacity provided by intersections having a different approach cross section. A 2 x 2 intersection is one at which all four approaches have a single thru lane (i.e., the intersection of two 2-lane undivided roadways). A 4 x 4 is the intersection of two 4-lane divided roadways (all four approaches have two thru lanes). The conditions assumed in calculation of the two capacities are as follows:

1. 10% of the 24-hour traffic carried in the peak hour (highest volume 60 minutes).
2. 10% left turns.
3. 10% right turns.
4. Separate left-turn and right-turn bays provided on all four approaches; dual left-turn bays assumed on all 4-lane and 6-lane facilities.
5. LOS D: 4-phase signal, 120-second cycle, maximum conflicting volume of 1,400 vph.
6. LOS C: 4-phase signal, 90-second cycle, maximum conflicting volume of 1,200 vph.
7. LOS B: 2-phase signal, 60-second cycle, maximum conflicting volume of 1,060 vph.

**Conditions**

- o 10% traffic in peak hour
- o 10% left-turns
- o 10% right-turns
- o left-turn bays on all approaches, dual left on 4 & 6 lane approaches
- o right-turn bay on all approaches
- o Los D: 120 sec. cycle, 4 phase conflict volume = 1400 vph
- o Los C: 90 sec. cycle, 4 phase, conflict volume = 12000 vph

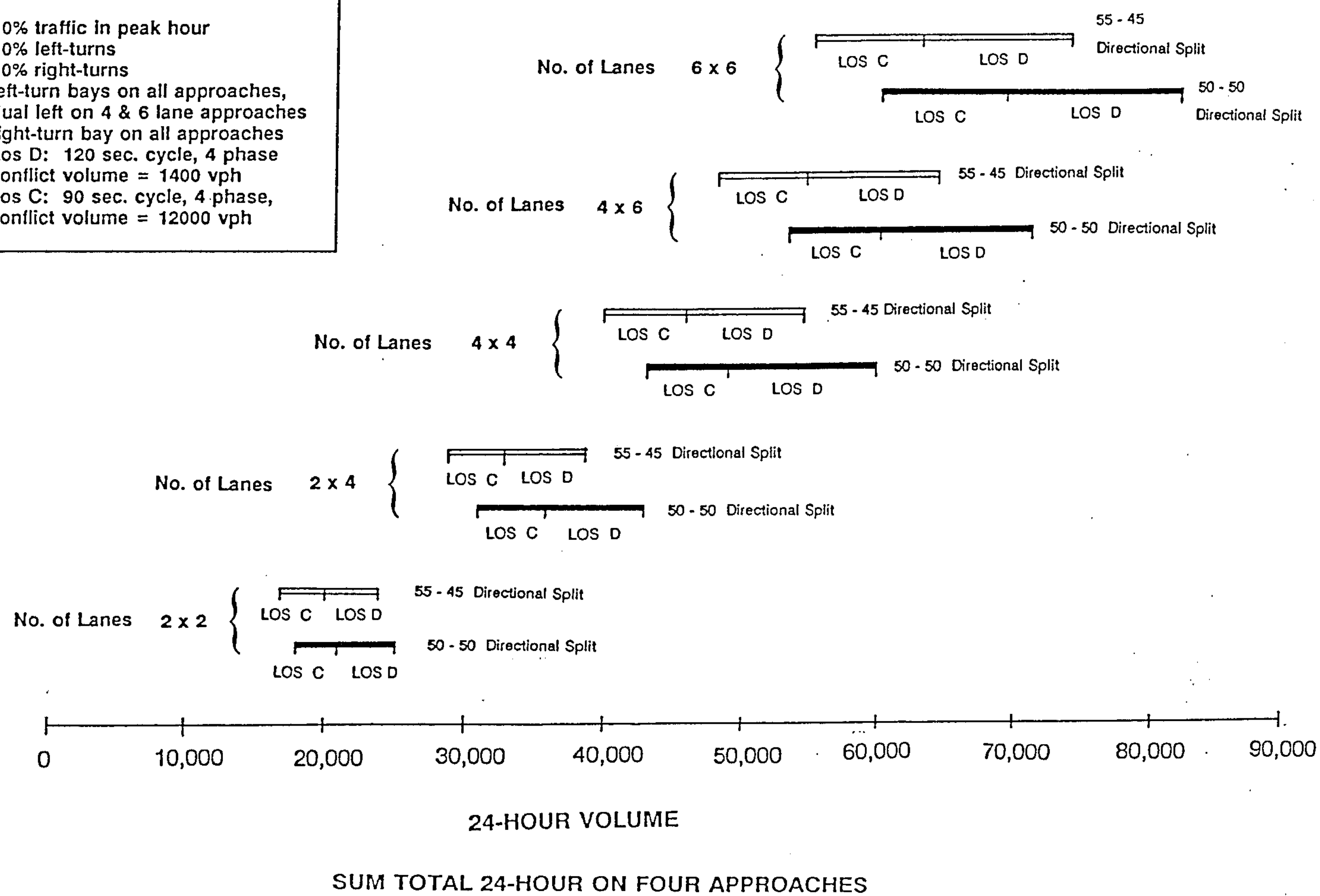



**FIGURE 3. Design Volumes**

The figure presents the capacity ranges for a 55/45 directional split and a 50/50 directional split. The 55/45 split probably represents a practical design condition, whereas the 50/50 split represents an optimistic or maximum physically possible condition.

The upper limits of LOS D are about 15% greater than the upper limits of LOS C (the boundary between LOS C and LOS D). This is approximately the error associated with traffic counts. This suggests that designing for LOS D is a questionable practice. A desirable practice is to design for the next larger intersection configuration when the forecast traffic assignment is within the LOS D range. For example, if the total assigned traffic on the four approaches is greater than about 46,000, the design should be an intersection of a 4-lane street with a 6-lane street rather than the intersection of two 4-lane streets. Depending upon the forecast traffic at other major intersections, the 6-lane cross section may be configured for a substantial distance or the cross section may be "flared" from 4 lanes to 6 lanes at the intersection in question.

An obvious characteristic shown in Figure 3 is the gap between the intersection of two 2-lane streets and the intersection of a 2-lane and a 4-lane divided street. As an extension of the preceding paragraph, when the total forecast 24-hour approach volume is more than 18,000 or 20,000 vpd, at least one of the intersection streets should be designed with 4 lanes (or flared to 4 lanes) at the intersection.

In some cases there is no overlap of the LOS D capacity and the LOS C capacity of the next larger intersection configuration (see Figure 3). For example, the upper limit of LOS D of a 2-lane street with a 4-lane street is about 39,000 vpd (for a 55/45 directional split). The LOS C capacity for an intersection of two 4-lane streets begins at about 40,000 vpd, whereas there is a substantial overlap between 4 x 4 and 4 x 6 as well as the 4 x 6 and 6 x 6 intersection configurations.

## LITERATURE REVIEW

System-level traffic data is not appropriate for project-level analysis and design. Therefore, an analyst must take the system-level data and manually reassign the traffic to a detailed schematic network representing all roadways and intersections within the corridor (project area) of interest. Such procedures are time consuming, costly and require considerable judgment on the part of an experienced analyst. Consequently, the results are not reproducible (at least not easily reproducible) by different analysts.

### NCHRP Report 255

The National Cooperative Highway Research Program sponsored research which produced an exhaustive study of procedures to translate system-level traffic assignment results into traffic data needed for individual highway project use (7). This project included the following three tasks:

1. Investigate procedures being used to develop data for project planning and design;
2. Develop and recommend appropriate procedures for the range of planning and design needs; and
3. Prepare a user's manual with illustrative case studies.

NCHRP Report 255 provides a good synthesis of the procedures that work best for developing project-level data from traffic assignments. This report represents the only major effort (1) in documenting standardized procedures that produce traffic data for use in project planning and design, (2) in establishing accepted procedures that translate various inputs into project traffic data, and (3) in specifying the contents, accuracies, and limitations of the data for the problem being addressed. The following general conclusions were presented in this report based on the finding of the research:

1. Traffic data are used for three primary purposes in highway project planning and design:
   (a) for evaluation of alternative highway improvement projects;

(b) for input to air quality, noise, and energy analyses of highway improvement projects; and

(c) for input to capacity and pavement analyses.

2. The traffic assignments that are produced by system-level computerized traffic assignment procedures must, in virtually all cases, be refined and subjected to further analysis in order that traffic data can be produced which can be used for highway project planning and design.
3. Until now there has been virtually no national standardization of procedures for the development of traffic data that are used as input to evaluation and environmental and design analyses. As a result, there are wide variations in the format and quality of traffic data produced by agencies.
4. Production of adequate traffic data requires considerable effort and time as well as judgment that comes with experience.
5. A large number of explicit assumptions are made every time traffic forecasts are performed for project planning and design studies.
6. It is important that the analyst applying the procedures have a general understanding of how the traffic data are to be used to insure that the proper data are prepared.
7. The users of the traffic data must understand the limitations and degree of uncertainty associated with traffic forecast data.

The appendix to NCHRP Report 255 is a user's guide which presents procedures for different applications on data needs. These, together with a brief statement of the purpose and methodology of each are as follows:

1. Preliminary Checks of Computerized Traffic Volume Forecasts

Purpose: To check the necessity of further refinement for the traffic forecasts.

Check 1: Examine the traffic forecasts with land use data assumptions.

Check 2: Compare future trip end summary to land use data assumptions.

Check 3: Examine highway network assigned by the future year traffic forecasts.

Check 4: Compare base year traffic count with the assigned volume of the base year.

Check 5: Compare the traffic forecasts with growth trends of link volumes, VMT, population, employment and households

2. Refinement of Computerized Traffic Volume Forecasts

Purpose: To document procedures that will allow for the refinement to take place in a rational and consistent manner.

(a) Screenline Refinement Process

Input data: Highway network with historical record, base year traffic counts, base year assignment, base year link capacity, and land-use growth trends

Procedure: Select screenline ----> check base year volume ----> perform computation ----> enter available data onto the calculation form ----> calculate adjustments due to base year assignment deviation ----> calculate %TCOUNT, %GCf, RAf/Cf and COUNT/Cb ----> perform final checks

(b) Select Link Analysis

Input data: Historical record network and trip table, future year traffic assignment

Procedure: Determine key links within the study area ----> prepare input data, run program, and check output ----> place output into refinement format ----> identify inconsistencies and errors ----> make refinement to traffic assignment

3. Traffic Data for Alternative Network Assumption

Purpose: To enable alternative highway projects to be effectively evaluated.

Application: Changes in roadway capacity, construction of parallel roadways, change in roadway alignment, and addition or deletion of roadway links.

(a) Modified Screenline Refinement Procedure

Application: For examining changes in roadway capacity and construction of parallel facility

Procedure: Apply screenline procedure for original future year network ----> repeat procedure using revised network data ----> compare assignment ---> perform reasonableness check ----> make final adjustment

(b) Modified Select Link/Zonal Tree Analysis

Application: For analyzing different roadway alignments, construction of parallel facilities, or the addition/subtraction of roadway links

Procedure: Refine assignment for original future year network ----> estimate magnitude of network change ----> determine link or zones for analyzing network changes ----> perform appropriate computer run ----> identify competing paths and compute new travel time ----> perform volume adjustment ----> make final check of volume/capacity ratio

4. Traffic Data for More Detailed Networks

Purpose: To produce a traffic assignment on a detailed highway network using available data.

Method: Subarea windowing, subarea focusing

Input data: Trip table, network, zonal land use, appropriate computer software

Procedure: Define study area ----> define new zone system and highway network ----> define trip table for revised network ----> assign trips to revised network ----> refine trip assignment within study area

5. Traffic Data for Different Forecast Years

Purpose: To produce traffic data for a target year that is different from that used in any computer forecasts.

Input data: Land-use projection, patterns of land use and traffic growth, staging of highway and transit facilities, available capacity of the roadway system, historical traffic trends, timetable of land-use development, and future year forecasts

Growth: Linear (uniform) or nonlinear (increasing growth decreasing growth, or stepped growth)

(a) Interpolation Method

For estimating traffic between two future year assignment, needs two sets of known values between which data can be generated

Procedure: Select assignments to bracket the desired year ----> determine the shape of the growth curve ----> calculate interpolation factor ----> perform computation

(b) Extrapolation Method

For estimating traffic for years beyond any available traffic forecast for years within a short time frame from the base year or when only one adequate traffic forecast is available

Procedure: Select forecast ----> determine the shape of the growth curve ----> calculate extrapolation factor ----> perform computation

6. Turning Movement Procedures

Purpose: To enable the analyst to develop the future year assignment of the turning movement.

Input data: Future year turning volume forecasts, directional and nondirectional volume forecasts, actual base year turning movement counts, desired time period, and number of intersection approaches

(a) Factoring Procedures: ratio method, different method, and combined method

(b) Iterative Method: directional volume method and nondirectional volume method

(c) "T" intersection procedures: nondirectional turning movement method and directional turning movement method

7. Design Hour Volume and Other Time of Day Procedures

Purpose: To forecast design hour volumes and peak hour factor.

(a) Design Hour Volume (DHV)

Objective: To select a specific hour of future traffic volume that will be used as the basis for design

Method: The hour at which the slope of the traffic volume curve changes most rapidly -- the 30th highest hour of the traffic volume curve

Result: 8%-12% of ADT (work travel), 12%-18% of ADT (recreational travel)

(b) DHV Forecasting Procedures for Typical Urban Facilities

Identify highway facility characteristics ----> select a PHT/ADT ratio ----> multiply the PHT/ADT ratio by the future ADT

(c) Peak Hour Factor

Definition: The ratio of the traffic carried during the peak 5-minutes of the peak hour to the total traffic carried during the peak hour (for freeways and expressways), the ratio of traffic carried during the peak 15 minutes of the peak hour to the total traffic carried during the peak hour (for arterials)

8. Directional Distribution Procedures

Purpose: Expecting the future change in directional distribution

(a) Procedure using modification of base year data

Input data: Future year traffic directional distribution, base year traffic distribution, future year work trip directional distribution, and base year work trip directional distribution

Procedure: Obtain estimate of the year directional distribution of peak hour traffic ----> determine the directional distribution of home to work travel in the base and future year ----> establish the reasonableness of base year estimated peak hour traffic directional distribution given the base year work travel directional distribution ----> forecast future year directional distribution by factoring base year directional distribution

(b) Procedure using anticipated future conditions

Input data: Future year forecasted peak hour traffic, estimated future year facility characteristics, and base year directional distributions on facilities with similar characteristics to those of future facility

Procedure: Identify the highway facility characteristics which influence directional distribution and the degree of influence of each characteristic ----> select a peak hour directional distribution based on the anticipated characteristics of the facility ----> multiply the future estimated peak hour directional distribution by the future year peak hour total traffic

(c) Procedure to adjust intersection directional link volumes

Input data: Hourly directional link volume on each approach

Procedure: Check volume totals ----> calculate the difference between the inbound and outbound movements ----> adjust the total inbound trips among approaches ----> calculate adjusted outbound movements for each hour ----> make final check

9. Vehicle Classification Procedures

Purpose: To forecast the vehicle classification of the future year.

Usage: Capacity analysis, pavement design, and environmental analysis

Consideration: The effects of forecasted land-use changes, long term vehicle classification counts

Procedure: Select base year vehicle classification ----> compare base year and future year land use ----> estimate the future year vehicle classification

10. Speed, Delay and Queue Length Procedures

Purpose: To calculate the future speed, delay and queue length.

Definition: Average speed, average running speed, operating speed, design speed queue and delay

Consideration: Under-capacity and over-capacity

(a) Speed procedure:

Input data: Design speed and volume-to-capacity ratio

Procedure: Apply design speed and volume-to-capacity ratio relationships to estimate average running speed ----> convert average running speed to operating speed

(b) Speed and delay procedure:

Input data: Signal cycle length, approach volume, flow rate, green time, green-to-cycle time ratio capacity

Procedure: Determine the mid-block average running speed ----> calculate intersection delay on each of the facility approaches ----> calculate total intersection delay on each of the facility approaches

(c) Queue length calculation procedures:

Input data: Approach flow rate, degree of saturation, cycle length, green-to-cycle time ratio

Procedure: Estimate the average proportion of vehicles stopping during a signal cycle ----> calculate the average queue length

11. Traffic Data for Design of Highway Pavements

In addition, the following three case studies are presented:

1. Use of refinement procedures for upgrading a limited access highway.
2. Use of windowing procedures for evaluating an arterial improvement.
3. Application of procedures for highway design.

The researchers recommend the following six areas of research:

1 The development of microcomputer of several procedures in a user's manual.
2. A need to better quantify factors influencing traffic growth.
3. A noniterative procedure to derive directional turning volumes to increase its applicability and to simplify its calculation.
4. Improved relationships between various highway speed groups.
5. An improved statistical base for transferring time-of-day, directional distribution, and vehicle classification data.
6. Quantifying truck time-of-day relationships.

A significant deficiency with the procedures presented in NCHRP Report 255 is that while it is suitable for a single intersection, the procedure is weak and very complex when applied to several intersections.

**S.I.T.E. Handbook**

The project-level traffic data desired for the traffic impact evaluation and design of proposed development includes individual movements (left, right, and thru) at all access drives to the proposed development, at all existing and proposed intersections adjacent to the proposed development, and at all intersections within the development areas of traffic influence. Procedures to develop such detailed project-level traffic data are presented in a report prepared for the Federal Highway Administration, Report No. FHWA/PL/85/105, "Site Impact Traffic Evaluation (S.I.T.E.) Handbook" (8). This report is available through the Institute of Transportation Engineers.

This manual presents analytical procedures (with examples) for the projection of traffic volumes by movement that will be generated at each access drive and intersection adjacent to and within the development's area of traffic influence. Such detailed project-level data are necessary to (a) access the traffic impact on the street system and nearby intersections, (b) evaluate the location and design of the proposed access drives, (c) evaluate the need for and effectiveness of changes in traffic operations and control of existing intersections within the area of traffic influence of the development, and (d) evaluate the need for and effectiveness of alternatives for the redesign of existing and proposed intersections within the area of traffic influence.

The procedures as presented in the S.I.T.E. Handbook are for manual calculations. However, consulting firms have developed microcomputer programs to assist in making the calculations, and various proprietary software packages are available.

**Other Research**

Eash, Janson, and Boyce (9) investigated the advantages and implications for practice of equilibrium trip assignment. The authors concluded that equilibrium trip assignment, rather than iterative assignment, should always be used on large networks especially for congested networks. They remarked that the method which best replicates the observed vehicle flows may depend on the detail of the network, the accuracy of the capacity-restraint functions, and the time period of the assignment. Finally, the authors concluded that the use of equilibrium assignment to produce 24-hour assignments may be inappropriate in that only the peak periods have truly congested flow. All-or-nothing assignments may be sufficient for off-peak periods.

Creighton and Hamburgh (10) developed a micro-assignment for simulating detailed vehicular movements in small areas. Unlike region-wide assignment approaches, this model has the ability to assign traffic to a finely coded street network for various time periods throughout the day. The time periods can be of short enough duration to reflect congestion realistically and are limited only by the practitioner's ability to obtain assigned trips by short time periods. Most O-D (origin-destination) surveys have time reported to the nearest one-tenth of an hour (six minutes).

Research by Stover, Woods, and Brudeseth (11) found that the application of volume-to-capacity relationships contained in the "Highway Capacity Manual," TRB Special Report 87, to traffic assignment produces "wide swings" in the impedance and assigned link volumes from one iteration to another. They concluded that the speed and V/C relationship used in traffic engineering was not applicable to traffic assignment. The researchers found that some "dampening" needed to be applied in order to achieve convergence in a capacity restraint assignment.

Benson and Cunagin (12) investigated the effects of implementing various impedance adjustment functions that could be applied to all over- or undercapacity links between each iteration on capacity restraint assignment. They concluded that the currently used capacity restraint functions are similar. The Bureau of Public Roads (BPR) function was found to be the most appropriate impedance adjustment function. The authors indicated that there were several problems with respect to developing capacity adjustment functions in the application of speed-flow relations in the assignment process. These problems occur for two reasons: (1) the most critical flow problems actually occur over short time spans, and (2) the assignment process may load a facility far in excess of capacity based upon some originally coded speed, but observed conditions are limited to some maximum capacity. As a result, capacity restraint functions might cause one to assign traffic to the links beyond some critical capacity.

Research by Stover and Woods (13) and Stover and Long (14) evaluated the effect of assignment results for zone size and network detail used in urban transportation planning studies. They concluded that there are no benefits, but several disadvantages, in the use of very detailed networks when using all-or-nothing assignments. The comparisons of traffic counts with the corresponding assigned volumes on arterial and major collector streets showed that assignment results were not improved with increased network detail.

Pratt (15) developed a screenline refinement process that can be used for refining system-level traffic assignments prior to their use for highway project planning and design. This procedure is used for refining traffic movements within a small- to medium-sized network and along highway corridors. The procedure also uses the relationship between base year traffic counts and future year capacities to adjust traffic crossing a prespecified screenline.

A sensitivity evaluation of traffic assignment by Stover, Buechler, and Benson (16) investigated the effect of the trip matrix on the traffic assignment results. They also evaluated the sensitivity of various measures of assignment accuracy commonly employed to evaluate traffic assignment results to detect differences in the assignment results. The researchers concluded that good assignment results will be achieved if the three following criteria are met: (1) there is a precise estimate of the total number of trip ends in the study area, (2) there is a precise estimate of the mean trip length (an error of $\pm 3\%$), and (3) there is a reasonable geographic distri0bution of trip ends. (The geographic distribution of trip ends can be achieved by using small zones in densely developed areas and large zones in sparsely developed areas, and then using the same number of trip ends in each zone.) They also concluded that percent root-mean-square (PRMS) error is the best measure and that vehicle miles of travel (VMT) is the least sensitive of the eight measures of assignment accuracy examined. The research demonstrated that, due to the aggregative nature of the assignment procedure, many differences that may be observed at the trip matrices tend to disappear in the assignment results.

Recent research by Chang (17) also investigated the sensitivity of the traffic assignment to different trip matrices generated from various constraints. He concluded that in small networks the traffic assignment was not sensitive to the trip matrices applied and was slightly more sensitive to the trip length frequency (TLF) constraint than the constraint of row and column totals (zonal productions and attractions).

Creighton and Hamburgh (18) presented an insight into the effect of assignment inaccuracy on the design process. They concluded that traffic forecast errors can have substantial impact on the project planning and design since the quality of traffic data for project planning and design is dependent upon the accuracy of the traffic forecasts. They also remarked that there is little likelihood that a plan would be prepared without some error in forecasts: either misadjustment or errors created by changes in the city that could not reasonably have been foreseen. As a result, they suggested a way to solve such errors, that is, "a regular monitoring activity" to identify problem areas and to determine whether changes in land use, trip generation, or trip length are having effects on traffic assignment accuracy. If problem areas are identified, then remedial actions can be taken. In sum, they concluded that the forecast errors are more sensitive to the planning than data, and they suggested that defensive measures and actions be created in the planning process to offset inevitable errors in the projection of the input variables.

A paper by Abu-Eisheh and Mannering (19) described a methodological package that can be readily applied to forecast the impacts of a range of transportation/facility-related improvements.

A recent paper by Fleet, Osborne, and Hooper (20) presented examples of practice based on techniques currently employed in planning and project development at both the state and local levels. This paper includes (1) background on the sources of traffic data, on traffic forecasting methodologies, as well as other planning considerations and (2) a perspective for planners on the utilization of traffic data in the project development process including pavement design. The article highlighted several key aspects for improving the basis for making project-level decisions, presented a framework for project development, and described a course developed to enhance connection between planning and project development. They also presented examples of spread sheet templates useful for applying the project-development procedure. In addition, they emphasized that planners and engineers must learn from each other and that they need to accept the importance, relevance, and necessity of each other's work.

The paper by Roden (21) described the features and advantages of "System II" which is defined as a regional information system and subarea analysis process computer package. He indicated that commercially available microcomputer planning models were inadequate for addressing detailed subarea studies; it was extremely difficult to use a modeling process designed for long-range regional planning studies to generate peak hour turning movementsat a series of critical intersections. On the other hand, the System II not only represented an extensive information system and a quick and easy method of addressing a wide range of regional issues but also was innovative, attractive, easy to use, and cost-effective.

# CHAPTER II. TEXAS CORRIDOR ANALYSIS PROCEDURE

## GENERAL CORRIDOR ANALYSIS GROUP PROCEDURE

The computerized system level traffic assignments require refinement before the assignment results are used for highway project planning and design. Although the procedures attempt to logically refine the results of the computerized modeling process by taking into account factors that cannot be adequately incorporated in the computer process, considerable professional judgment must be applied both during and following application of the procedures. The purpose of this chapter is to document the general procedures that are used in the Corridor Analysis Group of the Texas SDHPT.

Staff members of the Corridor Analysis Subsection of the Transportation Systems Planning Section (D-10P) were interviewed to obtain an understanding of the procedures currently in use. Collectively this staff represented a depth of experience and knowledge in corridor analysis garnered over many years of applications for each metropolitan area in the state.

The corridor analyst must take the traffic assignment results and manually reassign the traffic to a detailed schematic representing all the roadways within the corridor of interest. Currently the products produced by the Corridor Analysis Group are derived manually based on each individual analyst's experience and professional judgment. The assumptions and professional judgments used were documented to the extent practical. Key issues and decision parameters were highlighted. The general procedures used by the Corridor Analysis Group are summarized.

### Phase I: Existing

During Phase I, existing traffic is assigned to existing facilities.

1. Obtain straightline network. The straightline network is a simplification of the actual highway system that contains the study facility, intersecting arterials, and a zonal centroid called "area." The need to forecast traffic volumes for a major facility (highway or freeway) is usually the reason for conducting a corridor analysis. Each existing or proposed facility is represented by a

straight line. The Corridor Analysis Group calls this straightline network a "picture."

2. Collect existing traffic volumes. Traffic counts are obtained from a variety of sources:

   (a) Own counts: The traffic counts may be made by the Corridor Analysis Group or other D-10 staff. Through movements are counted by automatic count record equipment. Directional turning movement percentages may be obtained by counting or by direct observation. Turning movement percentages made by observation require professional judgment based on experience.

   (b) Freeway ramp map, semipermanent record, automatic traffic record, and/or automatic count record: Permanent count stations provide trend data. Average daily traffic estimates and annual average daily traffic estimates are available for locations with semi-permanent record and automatic traffic record equipment. The annual report from the permanent automatic traffic recorders shows for an estimate of volume for each location, the directional distribution, the peak-hour factor, and the K-factor. The semipermanent record location that is nearest the study area provides a starting point for estimating freeway volumes in the study area. The volumes in the study area are estimated by adding or subtracting counted ramp volumes recorded on the ramp map.

   (c) Others: Traffic counts are also obtained from traffic maps, urban studies, and projects files of previously completed adjacent corridor analysis studies. Information on new development that will impact volume estimates is obtained from SDHPT Districts Offices or from the consulting firm assisting with the project. The RI (road inventory) LOG is used for reference.

3. Calculate existing turn volumes and adjust approach volumes for each study area intersection or interchange using counted turn percentage data, observed

turning count percentages, or professional judgment. Two procedures are used depending on whether the intersection has three or four legs.

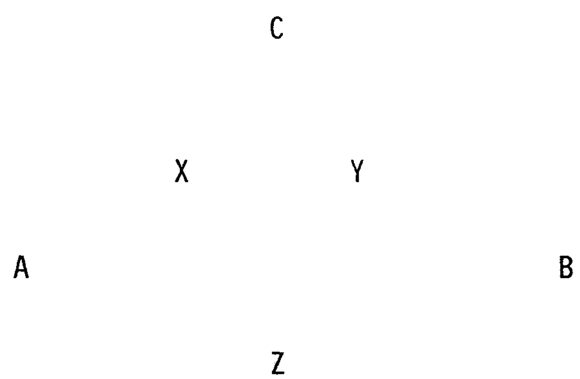
(a) Three-leg intersection: Directional turning volumes are computed directly from directional link volumes if one intersection movement is available. A unique solution is obtained for nondirectional turning movements if nondirectional link volumes for the three approaches are known. The following equations are used:

$Z = (A + B - C)/2$

$X = A - Z$

$Z = B - Z$

where A, B, and C are known link volumes; X and Y are the desired turning movements; and Z is the desired through movement (referring to the following diagram).




(b) Four-way intersection: Start with a known turn volume or if the turn volume is not available, start with the smallest turn leg. A unique solution is obtained for nondirectional turning movements if nondirectional link volumes on the four approaches are known. The following equations are used:

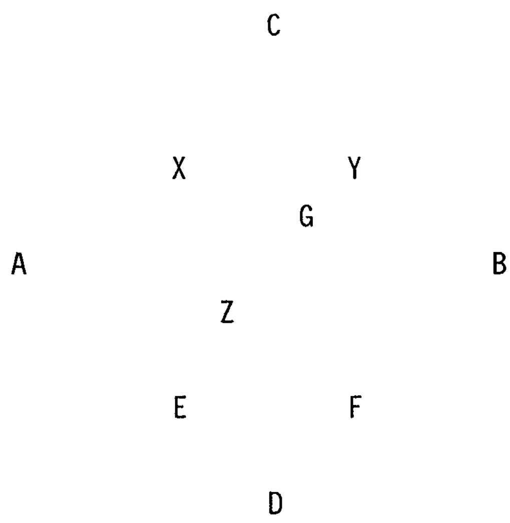
$G = D - (E+F)$

$Z = ((A-E) + (B-F) - (C-G))/2$

$X = (A-E) - Z$

$Y = (B-F) - Z$

where A, B, C, and D are known link volumes and E and F are known turn volumes; X and Y are the desired turning movements; and Z is the desired through movement (referring to the following diagram).




**Phase II: Existing with Improvements**

At the completion of Phase I, existing approach volumes and turning movements were estimated for all intersections and interchanges in the study area. During Phase II, existing traffic is diverted from the existing facility to the proposed facility.

1. Divert existing traffic volumes to the proposed facility based on an evaluation of the characteristics (speed and capacity) of the proposed facility and adjacent land use. Estimate approach volumes and turning movements for the proposed facility. This evaluation is based on professional judgment.
2. Adjust traffic volumes on existing facilities accounting for the diverted traffic.

**Phase III: Future with Improvements**

During Phase III, forecast traffic is estimated for existing and proposed facilities.

1. Calculate growth rates for existing and proposed facilities based on an analysis of historical counted traffic volumes. Regression analysis is used for facilities that exhibit linear growth rates. A simple linear regression equation is calculated in which the growth rate is constant over time. Professional judgment is used for facilities that do not exhibit linear growth rates or have

significant changes in adjacent land use. The following sources of information are used to establish an appropriate growth rate:

(a) Old traffic maps and historical data.

(b) Old project files.

(c) Historical and forecast adjacent land use.

(d) Growth rates for similar existing facilities within the same urban area.

(e) In general, lower growth rates are applied in completely developed areas; intermediate growth rates are applied in partially developed areas; and high growth rates are applied to undeveloped areas that are forecast to develop. The RI Log is used for reference.

2. Calculate future approach and turning movement volumes for the existing and proposed facilities by applying the appropriate growth rates to the traffic volumes estimated during Phase II.

**Phase IV: Future with Model Assignment**

During Phase IV, the forecast traffic assignment produced from the Texas Travel Demand Package are refined and posted to a detailed schematic.

1. Obtain and post on a straight line network map the future year approach and turning movement volumes produced by the Texas Large Network Assignment Models. Normally, these volumes are the result of a weighted capacity restraint assignment.

   Network coding practices used by D-10P vary by study area. For most urban areas, the networks are coded as two-way links with a single node representing an intersection or interchange. For these urban areas, the practice is to post the approach and turn volumes directly on the network map. For some urban areas, the freeways are detail coded. This means that the freeway main lanes are coded as two one-way links, ramps are coded as one-way links, and an interchange is coded using several nodes rather than as a single node. It is the practice of the Corridor Analysis Section to first collapse a detail coded network to a straight line network and collapse the approach and turning movement volumes as well prior to refining the traffic.

2. Revise the straight line network to match the schematic for the proposed facility. Schematic diagrams for proposed facilities are provided by the applicable District Office or D-8.

   Rarely does a detailed coded network match the schematic for a proposed facility. There are several reasons for this. The forecast year network is prepared months or even years before a detailed schematic is prepared. The schematic for a project will change several times during development of a project. And finally, the detail coded network for a proposed facility is almost never to the same degree of detail as the schematic used for project design.

3. Manually reassign the approach and turning movement volumes to the revised straight line network. Professional judgment is exercised at this stage for two reasons. The revised straight line network will, of course, not match the assigned network. The turning movement volumes obtained from a traffic assignment are subject to error.

**Phase V: Final Phase**

During Phase V, the straight line approach and turning movement volumes obtained from Phase III and Phase IV are compared, a decision made on the preferred forecast, and final volume refinements made to the schematic.

1. Compare the straight line approach and turning movement volumes developed in Phase III with those developed in Phase IV.

   Several factors are considered as part of this comparison. Frequently, the project year and 20-year forecast will be different than the years for which traffic assignments are available. Therefore, some interpolation of forecast volumes will almost always be necessary. The traffic assignment provides an excellent "pattern" of major traffic movements through a corridor or proposed project. The traffic assignment may have significant errors for specific turning movement volumes. The traffic assignment may be based on a different land-use forecast than the land-use forecast available at the time the corridor analysis is undertaken. This can be particularly significant if the location of a major traffic generator is known at the time of the corridor analysis, but only a general location was known when the traffic assignment was prepared. As a result of this evaluation one of three possible decisions is made: (1) use the Phase IV traffic assignment as is without significant modification, (2) use the Phase IV traffic assignment to establish the "pattern' and/or volume of movement through the corridor, or (3) reject the Phase IV traffic assignment as unreasonable for this particular corridor analysis and use the Phase III manual assignment.

2. Refine, as necessary, the approach and turning movement volumes on the selected straightline network. Reassign and post these volumes to the project schematic.

**AUSTIN US-290 CASE STUDY**

The Corridor Analysis Group procedures currently being used to develop highway traffic data for project planning and design in Texas urbanized areas were reviewed. The completed 2005 Austin network was selected. US-290 between US-183 and the new location of FM-973 was selected as the corridor analysis. The US-290 corridor involved a major land-use change, the proposed new Austin airport located near Manor. The proposed airport location is the northeast corner of the intersection of US-290 and FM-973. Figure 4 shows the US-290 study area.

The procedures developed in a TTI study entitled "Subarea Analysis Using Microcomputers" were used. The purpose of this case study was to investigate how close the subarea analysis procedures could come to the results from the Corridor Analysis Group and to evaluate if the subarea procedures' results were better than the Texas Package results based on the results from the Corridor Analysis Group. TRANPLAN/NEDS were used for the test.

Appendix A shows the US-290 study worksheet developed by the Corridor Analysis Group and the nondirectional volumes on the schematic straightline network. The following 2005 Austin network data (615 zones) were obtained from the SDHPT: Link data; production and attraction data; zonal radii data; and trip tables by the six trip purposes, a proposed airport trip table, and a total merged trip table.

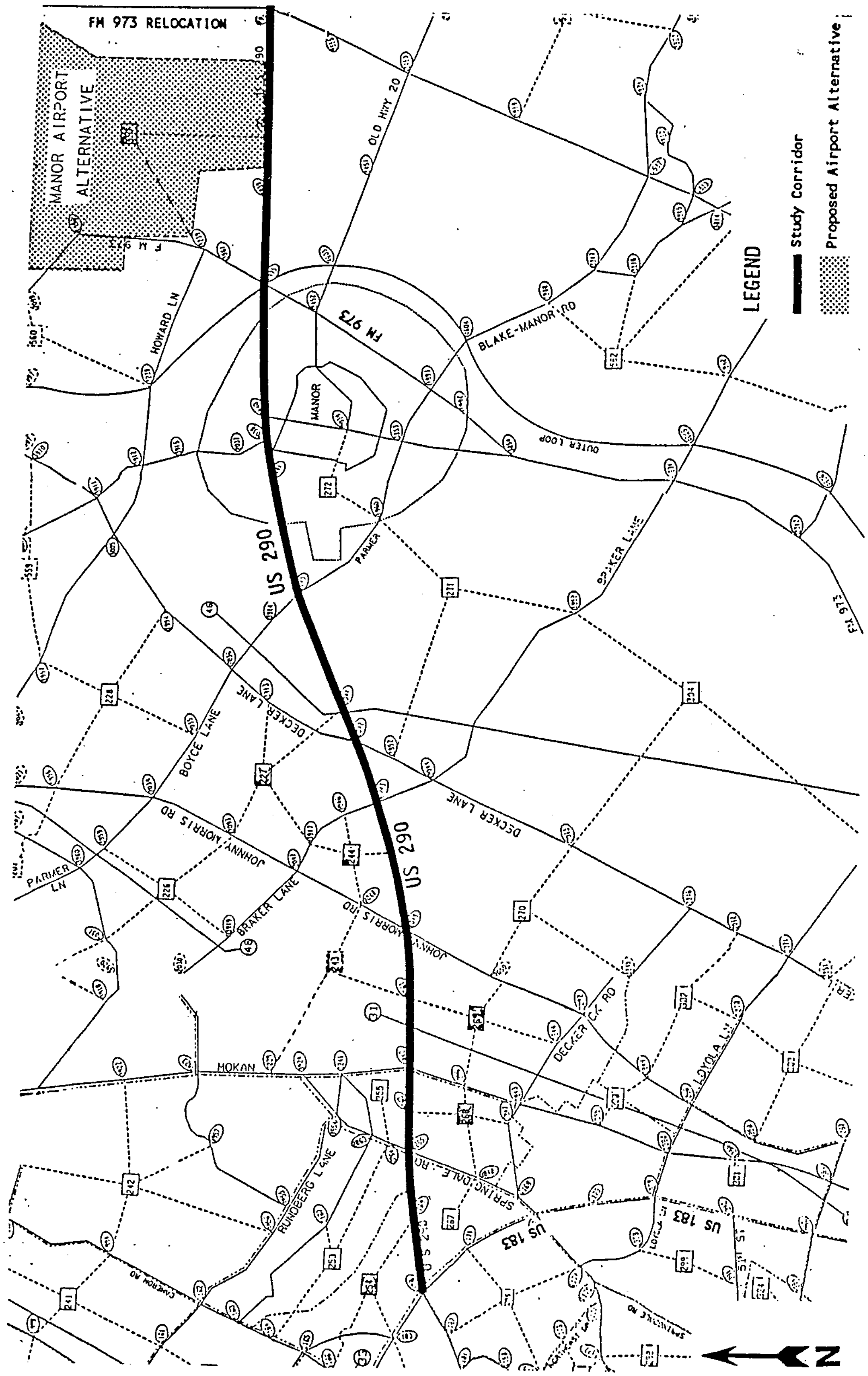



**FIGURE 4 US-290 Corridor Study Area Network.**

The 2005 Austin network and trip tables were downloaded to the microcomputer. The downloaded data were converted from the Texas Model format to TRANPLAN based on the following procedures:

1. Mount labeled tapes and allocate data sets on disk.
2. Copy from the tape data set to the allocated disk.
3. Convert binary record trip table to 12I6 format using the CVTRP program.
4. Download main frame to microcomputer.
5. Convert trip tables and link data from the Texas Model to TRANPLAN.

**Use of Entire Study Area**

The subarea assignment technique is primarily applicable to large urban areas. TRANPLAN capacities are sufficient to handle the entire Austin network. The subarea analysis procedures can be used in smaller urban areas without any recoding of the study area.

Every effort was made to obtain assigned volumes as close as possible to the volumes calculated by the Corridor Analysis Group. The traffic assignment programs in TRANPLAN were run using the following procedures:

1. Checked the downloaded (and converted to TRANPLAN) Austin trip tables using the selected zone parameter of the TRANPLAN Report Matrix function.
2. Ran the TRANPLAN Matrix Manipulate function to merge six trip tables (home-based-work, home-based-nonwork, nonhome-based, external-local, external-external, and truck-taxi trip purposes) into one total trip table.
3. Converted the total production and attraction (P/A) trip table to an origin and destination (O/D) trip table.
4. Ran the TRANPLAN Report Matrix function to be sure that the O/D trip table was converted correctly.
5. Converted the link data of the Texas Model to the TRANPLAN format using the link data conversion program developed by TTI.
6. Built the Austin highway network (2005) using the Build Highway Network

function in TRANPLAN.

7. Ran the traffic assignment using the five different techniques (all-or-nothing, stochastic, iterative, incremental and equilibrium assignments). The following parameters and options were used:

| Assign Techniques | Parameters and Options |
|---|---|
| All-or-nothing | Save Turn |
| Stochastic | Theta = 0.02 |
| Iterative | Iteration = 5 and Save Turn |
| Incremental | 15, 15, 20, 20, 30% and Save Turn |
| Equilibrium | Iteration = 5 and Save Turn |

The following nodes were selected along the study corridor (US-290 between US-183 and FM-973) for the turning movements using the following parameter specification:

SAVE TURNS = 1169, 1170, 1990, 1995, 2038, 2040-2043, 2045, 2049, 2061, 2062, 2065, 3837-3842

8. The Report Highway Load function was used to report assigned volumes from all five traffic assignment techniques. Turn volumes and selected link volumes on US-290 were obtained by using the following options:

| | |
|---|---|
| Minimum Report: | Any link with zero volume will not be reported. |
| Print Turns: | All nodes for which turn volumes were saved during loading are to be reported. |
| Suppress Links: | Only turn volumes are to be reported. |
| Turns File: | Turning movements are written to the TRNDATA file in ASCII format. |
| VC Report: | One-way V/C calculations are reported for all links selected, as well as the respective volumes and capacities. |

Table 2 shows the through and turn volumes along US-290 and the percent differences between the Corridor Analysis Group results and the TRANPLAN results. The multipath stochastic assignment does not have an option for the turning movement (no Save Turn option). The stochastic assignment produced assigned link volumes similar to the all-or-nothing assignment.

The schematic map was used for posting the turn and assigned volumes for each intersection. Appendix B shows the three different sources of the intersection volumes (from the Corridor Analysis Group, the Texas Package, and TRANPLAN) posted on three intersections along US-290. There was a significant difference between the manual calculation results from the Corridor Analysis Group and the results from TRANPLAN.

The results from the Texas Package were compared with TRANPLAN because there is a very significant difference between the manual calculation results of the Corridor Analysis Group and the TRANPLAN results. The TRANPLAN assigned link volumes were compared with the Texas Package volumes. The assigned (resulted) volumes from both packages using the all-or-nothing and capacity restraint assignment techniques were similar. The volume constraint assignments were tested by replacing the coded link capacities with the link volumes calculated by the Corridor Analysis Group. The volume constraint assignment results were not any better than the capacity restraint assignment results (see Table 2). This may be because there is no highway parallel to US-290.

Turning movement estimates for the intersection of US-290 and US-183 were studied (see Figure 5). The Corridor Analysis Group turning movement volumes as a proportion of through movements appeared high. For some reason which was not determined, the Corridor Analysis Group increased the number of trips going to or from Zone 254. On the original network, Zone 254 connected to three nodes and produced a total of 19,379 trip ends. On the network as revised by the Corridor Analysis Group, the link volume on the centroid connector to US-290, (the link from Node 254 to Node 1169) was 28,400 trips. A high percentage of these additional trips made a turn at the intersection of US-290 and US-183.

TABLE 2 THRU AND TURN VOLUME DIFFERENCE ALONG WITH US-290

| | | Corridor Results | All-Or-Nothing | | Incremental | | Equilibrium | | Vol.-Const. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Volume | % dif | Volume | % dif | Volume | % dif | Volume | % dif |
| US183 | N-W Turn | 16200 | 6610 (6635) | -59 | 5860 (5928) | -64 | 5332 | -67 | 6168 | -62 |
| | N-E Turn | 47100 | 30399 (30411) | -35 | 22643 (22871) | -52 | 23400 | -50 | 22021 | -53 |
| | S-W Turn | 35500 | 10783 (10788) | -70 | 10886 (9764) | -69 | 11067 | -69 | 10943 | -69 |
| | S-E Turn | 15400 | 2105 (2103) | -86 | 3081 (3426) | -80 | 3537 | -77 | 3054 | -80 |
| | E-W Thru | 40000 | 115523(115590) | 189 | 90232 (85336) | 126 | 87551 | 119 | 80992 | 103 |
| | N-S Thru | 51200 | 32475 (32506) | -37 | 60900 (60175) | 19 | 54860 | 7 | 61721 | 21 |
| Zone254 | N-W Turn | 26600 | 2765 | -90 | 3469 (3826) | -87 | 3711 | -86 | 4115 | -85 |
| | N-E Turn | 1800 | 2903 | 61 | 3308 (3357) | 84 | 3213 | 79 | 3134 | 74 |
| | E-W Thru | 75900 | 145262 | 91 | 112487(107807) | 48 | 110776 | 46 | 101952 | 34 |
| SPRING-DALE | N-W Turn | 5800 | 3588 | -38 | 9813 (8107) | 69 | 6422 | 11 | 12477 | 115 |
| | N-E Turn | 1100 | 1903 | -73 | 1303 (1257) | 18 | 1339 | 22 | 801 | -27 |
| | S-W Turn | 8000 | 3369 | -58 | 4836 (4751) | -40 | 3629 | -55 | 5311 | -34 |
| | S-E Turn | 5100 | 2079 | -59 | 2368 (1981) | -54 | 2564 | -50 | 1792 | -65 |
| | E-W Thru | 63900 | 141208 | 121 | 101146 (98306) | 58 | 103938 | 63 | 87298 | 37 |
| | N-S Thru | 3700 | 2701 | -27 | 4450 (4977) | 20 | 4631 | 25 | 4943 | 34 |
| Zone268 | S-W Turn | 600 | 1577 | 163 | 1273 (1239) | 112 | 1255 | 109 | 518 | -14 |
| | S-E Turn | 400 | 530 | 33 | 157 (161) | -61 | 265 | -34 | 165 | -59 |
| | E-W Thru | 69500 | 143613 | 107 | 103544(100305) | 49 | 106585 | 53 | 89373 | 29 |
| MOKAN | N-W Turn | 15600 | 48480 (48411) | 211 | 36990 (33164) | 137 | 38461 | 147 | 25114 | 61 |
| | N-E Turn | 2900 | 1787 (1396) | -38 | 1187 (995) | -59 | 1412 | -51 | 1451 | -50 |
| | S-W Turn | 8500 | 3956 (5114) | -53 | 1674 (2237) | -80 | 2730 | -68 | 1409 | -83 |
| | S-E Turn | 11400 | 11060 (11089) | -3 | 12481 (11525) | -9 | 12605 | 11 | 11404 | 0 |
| | E-W Thru | 45800 | 91707 (90581) | 100 | 65037 (65065) | 42 | 65658 | 43 | 63005 | 38 |
| | N-S Thru | 65400 | 36773 (37150) | -44 | 59149 (59702) | -10 | 63878 | -2 | 61299 | -6 |
| HILL LN | N-W Turn | 1900 | 3303 | 74 | 2487 | 30 | 2040 | 7 | 2500 | 32 |
| | S-E Turn | 800 | 72 | -91 | 74 | -91 | 36 | -96 | 156 | -81 |
| | E-W Thru | 47100 | 70456 | 50 | 49332 | 5 | 48305 | 3 | 52763 | 12 |
| | N-S Thru | 1800 | 731 | -59 | 659 | -63 | 717 | -60 | 3613 | 101 |
| OUTER LP | N-W Turn | 16500 | 18534 | 12 | 10620 | -36 | 10641 | -36 | 10644 | -35 |
| | N-E Turn | 4800 | 469 | -90 | 2780 | -42 | 4439 | -8 | 2691 | -44 |
| | S-W Turn | 6000 | 2743 | -54 | 1103 | -82 | 1471 | -75 | 1926 | -68 |
| | S-E Turn | 7400 | 457 | -94 | 5267 | -29 | 5558 | -25 | 3090 | -58 |
| | E-W Thru | 26200 | 27979 | 7 | 25946 | -1 | 24121 | -8 | 28829 | 10 |
| | N-S Thru | 7700 | 1538 | -80 | 1770 | -77 | 1695 | -78 | 1957 | -75 |
| Zone591 (Prop. Airport) | N-W Turn | 12000 | 0 (0) | -100 | 12918 (12961) | 8 | 14725 | 23 | 12982 | 8 |
| | N-E Turn | 2000 | 68 (76) | -97 | 70 (71) | -97 | 70 | -97 | 80 | -96 |
| | E-W Thru | 26400 | 29398 (29396) | 11 | 28808 (28921) | 9 | 29111 | 10 | 27342 | 4 |
| FM 973 | N-W Turn | 1200 | 109 (110) | -91 | 188 (199) | -84 | 153 | -87 | 47 | -96 |
| | N-E Turn | 600 | 1304 (1298) | 117 | 1971 (1859) | 229 | 1633 | 172 | 2007 | 235 |
| | S-W Turn | 1200 | 68 (67) | -94 | 68 (67) | -94 | 68 | -94 | 78 | -94 |
| | S-E Turn | 600 | 0 (0) | -100 | 0 (0) | -100 | 0 | -100 | 1285 | 114 |
| | E-W Thru | 26000 | 29289 (29286) | 13 | 28622 (28725) | 10 | 28960 | 11 | 27297 | 5 |
| | N-S Thru | 400 | 55 (54) | -86 | 55 (54) | -86 | 55 | -86 | 313 | -22 |

Note: The volumes in parentheses are from the Texas Package.

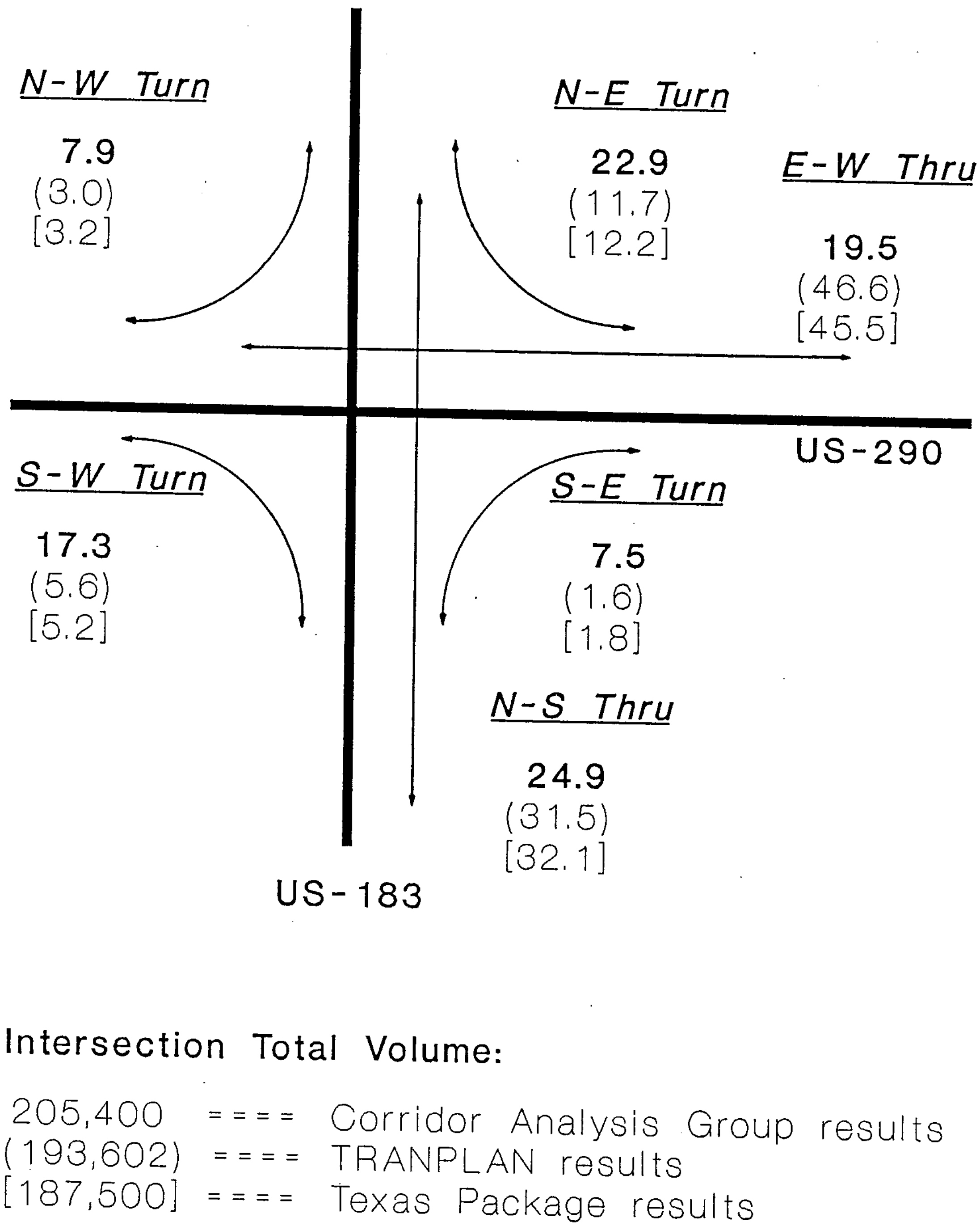



**FIGURE 5 Proportional Turning Movements at Intersection of US-290 and US-183. (Values in Percent)**

## Conclusions of US-290 Case Study

The US-290 case study compared assignments produced using the TRANPLAN subarea analysis procedures with the Corridor Analysis Group results. It was hoped that TRANPLAN subarea analysis procedures would produce "better" assignments than the Texas Package, "better" meaning assigned volumes closer to those developed by the Corridor Analysis Group. This did not occur. There was a significant difference between the TRANPLAN and Corridor Analysis Group assigned volumes. The Texas Package assignments and TRANPLAN subarea analysis assignments were similar. The volume constraint assignment results were similar to the capacity restraint assignment. None of the procedures tested were able to match the Corridor Analysis Group results.

# CHAPTER III. APPLICATION OF ALTERNATIVE PROCEDURE

## ALTERNATIVE PROCEDURE

Corridor analysis needs to be performed using standardized and documented procedures, and, to the extent practical, microcomputer software. This will help assure the production of the high quality, consistent, and timely forecasts. However, the procedures must be applied with considerable judgment by a trained analyst. The following alternative procedures were developed and are recommended for evaluation by the Corridor Analysis Group.

### Phase I: Existing

During Phase I, existing traffic is assigned to existing facilities.

1. Obtain straightline network. The straightline network is a simplification of the actual highway system that contains the study facility, intersecting arterials, and a zonal centroid called "area." The need to forecast traffic volumes for a major facility (highway or freeway) is usually the reason for conducting a corridor analysis. Each existing or proposed facility is represented by a straight line. The Corridor Analysis Group calls this straightline network a "picture."
2. Collect existing traffic volumes. Traffic counts are obtained from a variety of sources.
   - (a) Own counts: The traffic counts may be made by the Corridor Analysis Group or other D-10 staff. Through movements are counted by automatic count record equipment. Directional turning movement percentages may be obtained by counting or by direct observation. Turning movement percentages made by observation require professional judgment based on experience.
   - (b) Freeway ramp map, semipermanent record, automatic traffic record, and/or automatic count record: Permanent count stations provide trend data. Average daily traffic estimates and annual average daily

traffic estimates are available for locations with semipermanent record and automatic traffic record equipment. The annual report from the permanent automatic traffic recorders shows for an estimate of volume for each location, the directional distribution, the peak-hour factor, and the K-factor.

The semipermanent record location that is nearest the study area provides a starting point for estimating freeway volumes in the study area. The volumes in the study area are estimated by adding or subtracting counted ramp volumes recorded on the ramp map.

(c) Others: Traffic counts are also obtained from traffic maps, urban studies, and projects files of previously completed adjacent corridor analysis studies. Information on new development that will impact volume estimates is obtained from SDHPT Districts Offices or from the consulting firm assisting with the project. The RI (road inventory) LOG is used for reference.

3. Calculate existing turn volumes and adjust approach volumes for each study area intersection or interchange using counted turn percentage data, observed turning count percentages, or professional judgment. Two procedures are used depending on whether the intersection has three or four legs.

(a) Three-leg intersection: Directional turning volumes are computed directly from directional link volumes if one intersection movement is available. A unique solution is obtained for nondirectional turning movements if nondirectional link volumes for the three approaches are known. The following equations are used:

$Z = (A + B - C)/2$

$X = A - Z$

$Z = B - Z$

where A, B, and C are known link volumes; X and Y are the desired turning movements; and Z is the desired thru movement (referring to the next diagram).

C

X Y

A B

Z

(b) Four-way intersection: Start with a known turn volume or if the turn volume is not available, start with the smallest turn leg. A unique solution is obtained for nondirectional turning movements if nondirectional link volumes on the four approaches are known. The following equations are used:

G = D - (E+F)

Z = ((A-E) + (B-F) - (C-G))/2

X = (A-E) - Z

Y = (B-F) - Z

where A, B, C, and D are known link volumes and E and F are known turn volumes; X and Y are the desired turning movements; and Z is the desired thru movement (referring to the following diagram).

C

X Y

G

A B

Z

E F

D

**Phase II: Existing with Improvements**

At the completion of Phase I, existing approach volumes and turning movements were estimated for all intersections and interchanges in the study area. During Phase II, existing traffic is diverted from the existing facility to the proposed facility.

1. Divert existing traffic volumes to the proposed facility based on an evaluation of the characteristics (speed and capacity) of the proposed facility and adjacent land use. Estimate approach volumes and turning movements for the proposed facility. This evaluation is based on professional judgment.
2. Adjust traffic volumes on existing facilities accounting for the diverted traffic.

**Phase III: Run Base Year Traffic Assignment Using Subarea Analysis**

1. Define the subarea including, if possible, at least two parallel roadways within the study corridor.
2. Set up a run of the Texas Large Network Assignment Model to assemble the full study area network, and then run the Subarea Windowing Program.
3. Download the data (i.e., link data, zonal productions and attractions, radii data, fifth relative values, XY coordinates, and trip tables) to microcomputer.
4. Convert the downloaded data from the Texas Package format to TRANPLAN.
5. Revise the future network into the detailed (schematic) network if needed.
6. Run the TRANPLAN traffic assignments.

**Phase IV. Validate Model and Run Future Year Assignment Using Subarea Analysis**

**Phase VI. Refine Future Year Link Volumes Using Factoring Procedures**

The computations are to adjust the future year link volumes to account for probable assignment errors. The underlying assumption used is that errors occurring in a base year assignment will continue to occur proportionally in any future year assignment. A future year link volume is adjusted using two methods: (1) the ratio of the adjusted base year traffic count on the existing network with improvements (results from Phase II) to the validated base year assignment (results from Phase IV) and (2) the numerical difference between the adjusted base year traffic count and the validated base year assignment. Then, a subsequent adjustment is made which is the average of the two methods.

1. Input Data and Output:
   (a) Future year assigned volume ($F_i$) from Phase V.
   (b) Base year assigned volume ($B_{ai}$) from Phase IV.
   (c) Base year ground counts ($B_{ci}$) from Phase II.
   (d) Output: Adjusted future year link volume ($V_i$).
2. Ratio Method: $V_{ri} = F_i \times (B_{ci}/B_{ai})$
3. Difference Method: $V_{di} = F_i + (B_{ci}-B_{ai})$
4. Combined Method: $V_{fi} = (V_{fi}+V_{di})/2$

**Phase VII. Calculate Future Turning Movements Using Iterative Procedures**

The iterative procedures adjust future year turning movements to match as closely as possible a predetermined estimate of turning percentages. The turning movement iterative procedures are from NCHRP Report 255, pages 105-108 (7). Iteration involves applying a technique repeatedly until the results converge to an acceptable result. Iteration is required to balance the volume of traffic entering and leaving the intersection. Future year link volumes are fixed using this method and the turning movements are adjusted to match.

1. Input Data:
   (a) Future year directional link volumes from Phase VI.
   (b) Initial estimate of future directional turning percentages from Phase II.
2. Iterative Procedures:
   (a) Step 1: Construct initial turning movement matrix.
   (b) Step 2: Perform the first row iteration.
   (c) Step 3: Perform the first column iteration.
   (d) Step 4: Repeat row iteration.
   (e) Step 5: Repeat column iteration.
   (f) Step 6: Continue the iterations until acceptable values are obtained.

Note: The final adjusted directional turning and thru movements should be reviewed for reasonableness.

## SH-161 CASE STUDY IN DALLAS-FORT WORTH

The SH-161 project was selected for evaluation of the proposed alternative procedures. Only part of the alternative procedures were able to be evaluated because the base year data was not available. The alternative procedure results were compared to the Corridor Analysis Group results. The proposed SH-161 from IH-20 to IH-635 in the D-FW area (see Figure 6) was chosen because the project, including the forecast average daily traffic volumes and turning movements, had already been completed by the Corridor Analysis Group.

The purpose of this case study was to test the alternative procedures. The alternative procedures are intended to reduce the manual work required by substituting travel demand modeling software for a part of the manual labor. The proposed SH-161 runs through Irving and Grand Prairie, connects with IH-635 on the north, intersects IH-30 in the middle, and connects with IH-20 on the south. The year 2010 D-FW total trip table and the future network with improvements were provided by the SDHPT Regional Planning Office in Arlington. A series of network plots associated with the improvements were provided as well.

### Subarea Window Procedure

The microcomputer packages have different network design limits. The network size limits also vary according to the amount of main memory available. TRANPLAN is designed for 3,000 zones and 32,000 links; however, 1,500 zones, 8,000 nodes, and 9,000 links can be processed on a 640 Kbytes-RAM microcomputer. The subarea assignment technique is primarily applicable to studies in large areas such as San Antonio, Houston-Galveston, and Dallas-Fort Worth.

TTI Research Report 1110-4F (22) provides a detailed description of subarea analysis procedures. A major application of subarea analysis is the study of proposed future land-use and transportation alternatives. A subarea assignment technique is applicable to alternatives involving major changes to the transportation system, major land-use changes, or both. The proposed SH-161 project is a major change to the transportation system.

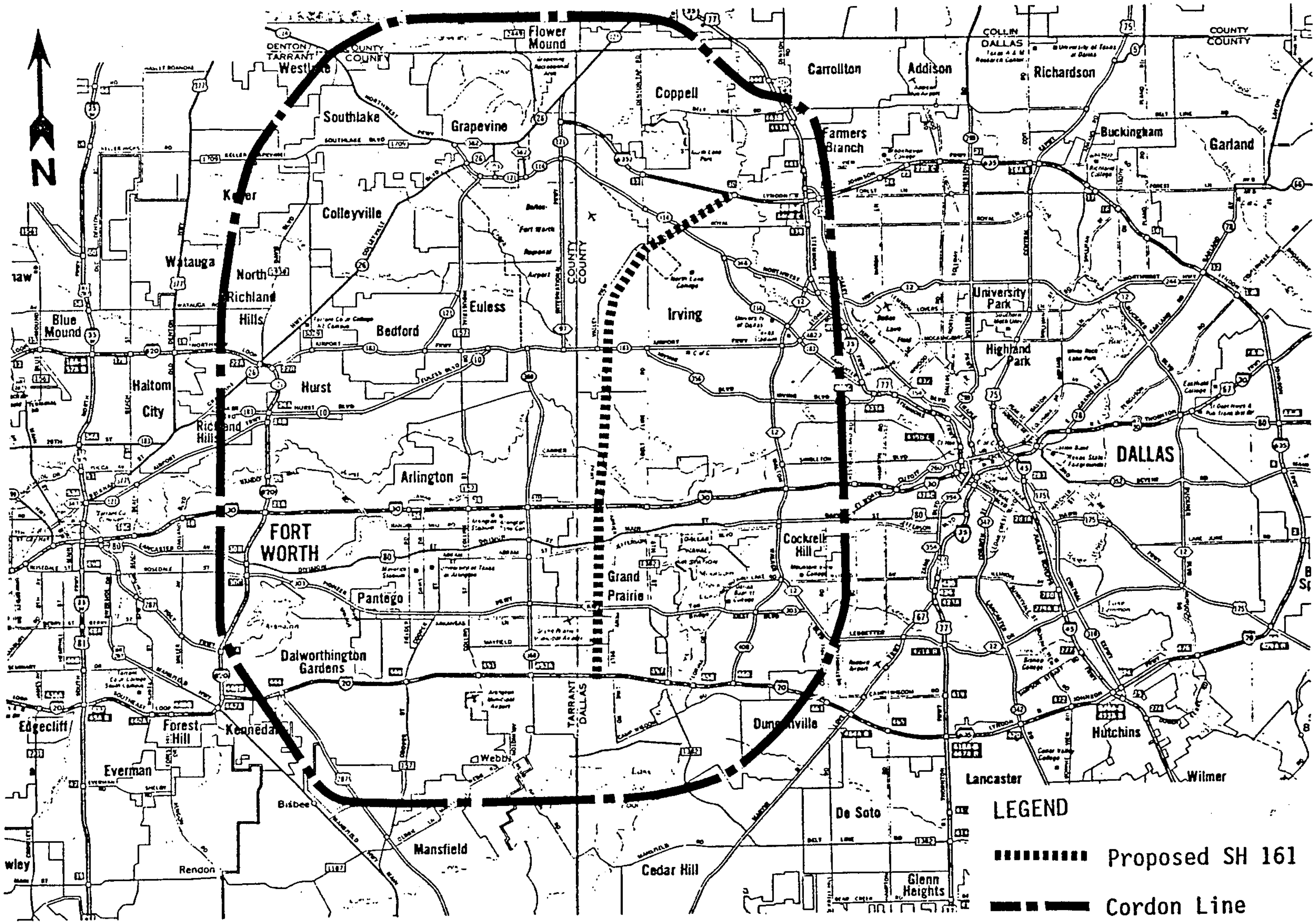



FIGURE 6 SH-161 Corridor Study Area.

One of the subarea assignment approaches, the subarea window approach, was used in this case study. Using this approach, the subarea was identified and only those zones and the network within the subarea were carried forward in the subarea analysis procedure. In essence, the network and zones within the subarea were isolated and treated as a small stand-alone study area. Traffic entering or leaving the subarea was treated as external traffic relative to the subarea. The subarea's external traffic is predominantly composed of internal traffic relative to the larger study area.

**Use of Subarea Window Technique in Texas Package**

1. Chose the approximate area of the subarea along SH-161. The subarea was a substantially larger area than the subarea of interest. The window area covered West Loop 12 in Dallas and East Loop IH-820 in Fort Worth.
2. Drew a cordon line on the map which surrounds the subarea. The following rules were used:
   (a) The subarea cordon line should not pass through any nodes or centroids.
   (b) When the cordon line intersected a centroid connector, the associated centroids were inside the cordon line. Each node immediately outside the cordon became an external station for the subarea. A centroid should not function as an external station.
   (c) The cordon line should not intersect (1) a zonal centroid connector which had only one centroid connector or (2) all the centroid connectors that a zonal centroid had because the internal trips from or to that zone were isolated.
   (d) The windowed subarea should be completely closed without any missing external station link.
3. Checked the cordon line to insure that it completely surrounded the subarea and that it followed the rules above. The Path Trace function in the Texas Package was employed to check if there were any missing links.
4. Chose a link intersected by the cordon line and recorded all links and

connectors crossed by the cordon line. Each link, called an External Station Link, was entered on an External Station Link card image.

5. Picked a centroid inside the cordon line and entered the centroid number on the Direction Card image. Centroid 973 was chosen as the zone inside the cordon line.
6. Set up a run of the Texas Large Network Assignment Models to assemble the full study area network and then ran the Subarea Windowing program. This program renumbered the centroids within the subarea starting at "1." Then the nodes which constitute the external stations were renumbered.
7. Examined the run. There were errors in the external station links. The errors were corrected and the program was rerun.
8. Ran trip matrix collapse and saved the resulting windowed trip matrix.

**Downloading Procedure**

The conversion (i.e., downloading and/or uploading) program which is a part of the subarea analysis was used. Two output data sets from the subarea window program, total trip table and link data, were generated and downloaded from the Texas Package to TRANPLAN. Node numbers larger than 9,999 had to be renumbered because TRANPLAN can handle a maximum of 9,999 nodes. The renumbered node numbers were inserted into gaps between Node 1 and Node 9,999.

The downloaded/windowed network consisted of 444 internal zones, 118 external stations, 1,098 internal centroid connectors, and 4,764 nondirectional (two-way) links. The windowed network was revised into the detailed schematic network. Forty new links were added along SH-161. The Build Highway Network program in TRANPLAN was run.

**Use of Traffic Assignment**

The incremental assignment in TRANPLAN was run. In order to get the turning movement result from the TRANPLAN traffic assignment, the following steps were needed:

1. Select a series of interchanges on SH-161 (usually three to six interchanges

with less than 50 nodes because TRANPLAN can save turn volumes up to 50 nodes during one loading).

2. Recode all node numbers inside the selected interchanges.
3. Run TRANPLAN with the parameter specification as <u>SAVE TURNS = list of nodes</u>.

The study area was divided into three portions: south, central, and north. Three interchanges were selected in each portion for the turning movement comparisons. The comparisons of the TRANPLAN results with the Corridor Analysis Group Results are shown in Table 3 (south portion), Table 4 (central portion), and Table 5 (north portion). Turning movement volumes from the Texas Travel Demand Model using the entire D-FW network are also included in Tables 3, 4, and 5. Appendix C shows an example of the turning movements for one intersection. There was a significant difference between the results of the Corridor Analysis Group and TRANPLAN. The comparison between the Texas Travel Demand Model and TRANPLAN using the subarea window assignment technique resulted in similar thru and turning movement volumes.

Like most modeling packages, TRANPLAN assigned "zero" turning and thru volumes at some intersections (see Figure 7). The locations with "zero" assigned volumes were investigated and identified:

1. U-turn underpass of freeway: No zonal centroids near the frontage road. In TRANPLAN, drivers are assumed to be 100 percent rational and make no mistakes in choosing their routes. However, in reality, the U-turn underpass of a freeway is frequently used by drivers who miss their intended exit and need to return to some upstream locations.
2. Thru movement on frontage road: No zonal centroids near the frontage road.
3. Turn movements from or to frontage road: No zonal centroids toward the turning direction. Alternative routes are available that take shorter travel time.

In summary, two reasons explain most of these "zero" assigned volumes: (1) A centroid is an assumed point in a zone that represents the origin or destination of all trips to or from the zone and (2) the path algorithm is based on the minimum path.

TABLE 3 VOLUME COMPARISONS IN SOUTH PORTION OF SH-161

| Location (Intersected Street) | | Movements | Corridor Results | Texas Pack Results | TRANPLAN Results |
|---|---|---|---|---|---|
| S-1 | Mayfield Road | N-W Turn (R) | 1100 | 342 | 314 |
| | | N-E Turn (L) | 5500 | 1525 | 1394 |
| | | S-E Turn (R) | 2600 | 3063 | 2675 |
| | | S-W Turn (L) | 700 | 675 | 1036 |
| | | E-N Turn (R) | 5300 | 1260 | 1278 |
| | | E-S Turn (L) | 4100 | 4586 | 4583 |
| | | W-S Turn (R) | 700 | 696 | 703 |
| | | W-N Turn (L) | 1200 | 432 | 453 |
| | | N-S Thru (T) | 6500 | 3290 | 3165 |
| | | S-N Thru (T) | 7500 | 4238 | 4500 |
| | | E-W Thru (T) | 700 | 123 | 180 |
| | | W-E Thru (T) | 700 | 117 | 135 |
| | | N-N Turn (U) | 2600 | 2447 | 994 |
| | | S-S Turn (U) | 400 | 0 | 0 |
| | TOTAL | | 39600 | 22794 | 21410 |
| S-2 | Warrior Trail | N-W Turn (R) | 3800 | 5114 | 3869 |
| | | N-E Turn (L) | 2700 | 3892 | 3778 |
| | | S-E Turn (R) | 1000 | 0 | 0 |
| | | S-W Turn (L) | 2400 | 2418 | 2185 |
| | | E-N Turn (R) | 3100 | 4347 | 3944 |
| | | E-S Turn (L) | 1000 | 0 | 129 |
| | | W-S Turn (R) | 1000 | 0 | 0 |
| | | W-N Turn (L) | 2600 | 3916 | 5295 |
| | | N-S Thru (T) | 1000 | 0 | 0 |
| | | S-N Thru (T) | 1000 | 0 | 0 |
| | | E-W Thru (T) | 1500 | 999 | 974 |
| | | W-E Thru (T) | 1100 | 569 | 749 |
| | TOTAL | | 22200 | 21255 | 20923 |
| S-3 | Arkansas Lane | N-W Turn (R) | 500 | 0 | 0 |
| | | N-E Turn (L) | 600 | 0 | 0 |
| | | S-E Turn (R) | 3400 | 1406 | 1413 |
| | | S-W Turn (L) | 700 | 743 | 1337 |
| | | E-N Turn (R) | 800 | 0 | 0 |
| | | E-S Turn (L) | 3500 | 1471 | 1473 |
| | | W-S Turn (R) | 1800 | 1765 | 1591 |
| | | W-N Turn (L) | 500 | 0 | 0 |
| | | N-S Thru (T) | 8400 | 8195 | 6952 |
| | | S-N Thru (T) | 7900 | 7573 | 8609 |
| | | E-W Thru (T) | 700 | 696 | 759 |
| | | W-E Thru (T) | 1000 | 964 | 1012 |
| | | N-N Turn (U) | 600 | 0 | 0 |
| | | S-S Turn (U) | 200 | 0 | 0 |
| | TOTAL | | 30600 | 22813 | 23146 |

TABLE 4 VOLUME COMPARISONS IN CENTRAL PORTION OF SH-161

| Location (Intersected Street) | | Movements | Corridor Results | Texas Pack Results | TRANPLAN Results |
|---|---|---|---|---|---|
| C-1 | Oakdale Road | N-W Turn (R) | 600 | 592 | 608 |
| | | N-E Turn (L) | 200 | 111 | 107 |
| | | S-E Turn (R) | 1000 | 273 | 300 |
| | | S-W Turn (L) | 2400 | 2938 | 2930 |
| | | E-N Turn (R) | 300 | 155 | 125 |
| | | E-S Turn (L) | 1000 | 1017 | 1015 |
| | | W-S Turn (R) | 2400 | 2877 | 2921 |
| | | W-N Turn (L) | 600 | 602 | 458 |
| | | N-S Thru (T) | 1200 | 0 | 0 |
| | | S-N Thru (T) | 1600 | 1139 | 1153 |
| | | E-W Thru (T) | 400 | 33 | 33 |
| | | W-E Thru (T) | 300 | 19 | 19 |
| | TOTAL | | 12000 | 9756 | 9669 |
| C-2 | Shady Grove Road | N-W Turn (R) | 600 | 247 | 247 |
| | | N-E Turn (L) | 400 | 420 | 372 |
| | | S-E Turn (R) | 4700 | 5356 | 5362 |
| | | S-W Turn (L) | 1300 | 712 | 738 |
| | | E-N Turn (R) | 400 | 0 | 16 |
| | | E-S Turn (L) | 4700 | 4648 | 5365 |
| | | W-S Turn (R) | 1000 | 461 | 473 |
| | | W-N Turn (L) | 500 | 496 | 567 |
| | | N-S Thru (T) | 1200 | 497 | 505 |
| | | S-N Thru (T) | 8200 | 8589 | 8234 |
| | | E-W Thru (T) | 1000 | 1433 | 1494 |
| | | W-E Thru (T) | 1300 | 1656 | 2057 |
| | | N-N Turn (U) | 200 | 225 | 546 |
| | | S-S Turn (U) | 200 | 0 | 0 |
| | TOTAL | | 25700 | 24740 | 25976 |
| C-3 | Rochelle Road | N-W Turn (R) | 2000 | 0 | 0 |
| | | N-E Turn (L) | 1600 | 1588 | 2392 |
| | | S-E Turn (R) | 300 | 0 | 0 |
| | | S-W Turn (L) | 300 | 3045 | 3006 |
| | | E-N Turn (R) | 1600 | 0 | 0 |
| | | E-S Turn (L) | 600 | 0 | 0 |
| | | W-S Turn (R) | 600 | 0 | 0 |
| | | W-N Turn (L) | 2000 | 1984 | 2417 |
| | | N-S Thru (T) | 1400 | 2369 | 1905 |
| | | S-N Thru (T) | 1700 | 1144 | 1990 |
| | | E-W Thru (T) | 700 | 237 | 314 |
| | | W-E Thru (T) | 1000 | 533 | 0 |
| | | N-N Turn (U) | 200 | 0 | 0 |
| | | S-S Turn (U) | 600 | 0 | 0 |
| | TOTAL | | 14600 | 10900 | 12024 |

TABLE 5 VOLUME COMPARISONS IN NORTH PORTION OF SH-161

| Location (Intersected Street) | | Movements | Corridor Results | Texas Pack Results | TRANPLAN Results |
|---|---|---|---|---|---|
| N-1 | Royal Lane | N-W Turn (R) | 1500 | 42 | 0 |
| | | S-E Turn (R) | 9100 | 7937 | 8498 |
| | | E-N Turn (R) | 1500 | 0 | 0 |
| | | W-S Turn (R) | 9000 | 7807 | 7556 |
| | | N-S Thru (T) | 12000 | 13379 | 13004 |
| | | S-N Thru (T) | 12700 | 17264 | 14758 |
| | TOTAL | | 45800 | 46429 | 43816 |
| N-2 | MacArthur Blvd | N-W Turn (R) | 2000 | 0 | 0 |
| | | N-E Turn (L) | 1100 | 1072 | 1648 |
| | | S-E Turn (R) | 2500 | 2453 | 2305 |
| | | S-W Turn (L) | 3900 | 6969 | 4605 |
| | | E-N Turn (R) | 800 | 162 | 488 |
| | | E-S Turn (L) | 3600 | 6805 | 5409 |
| | | W-S Turn (R) | 3900 | 3903 | 3254 |
| | | W-N Turn (L) | 2000 | 0 | 0 |
| | | N-S Thru (T) | 2200 | 1580 | 2507 |
| | | S-N Thru (T) | 2000 | 0 | 0 |
| | | E-W Thru (T) | 10600 | 4989 | 5602 |
| | | W-E Thru (T) | 8800 | 8847 | 7795 |
| | TOTAL | | 43400 | 36780 | 33613 |
| N-3 | Buffalo Blvd | N-W Turn (R) | 3000 | 0 | 0 |
| | | N-E Turn (L) | 3800 | 0 | 439 |
| | | S-E Turn (R) | 2900 | 5869 | 7360 |
| | | S-W Turn (L) | 3800 | 0 | 0 |
| | | E-N Turn (R) | 1800 | 0 | 0 |
| | | E-S Turn (L) | 4500 | 7509 | 8474 |
| | | W-S Turn (R) | 3800 | 0 | 0 |
| | | W-N Turn (L) | 3000 | 0 | 0 |
| | | N-S Thru (T) | 6600 | 16565 | 18201 |
| | | S-N Thru (T) | 7200 | 162 | 488 |
| | | E-W Thru (T) | 6000 | 8023 | 7834 |
| | | W-E Thru (T) | 3800 | 3809 | 6707 |
| | TOTAL | | 50200 | 41937 | 49503 |

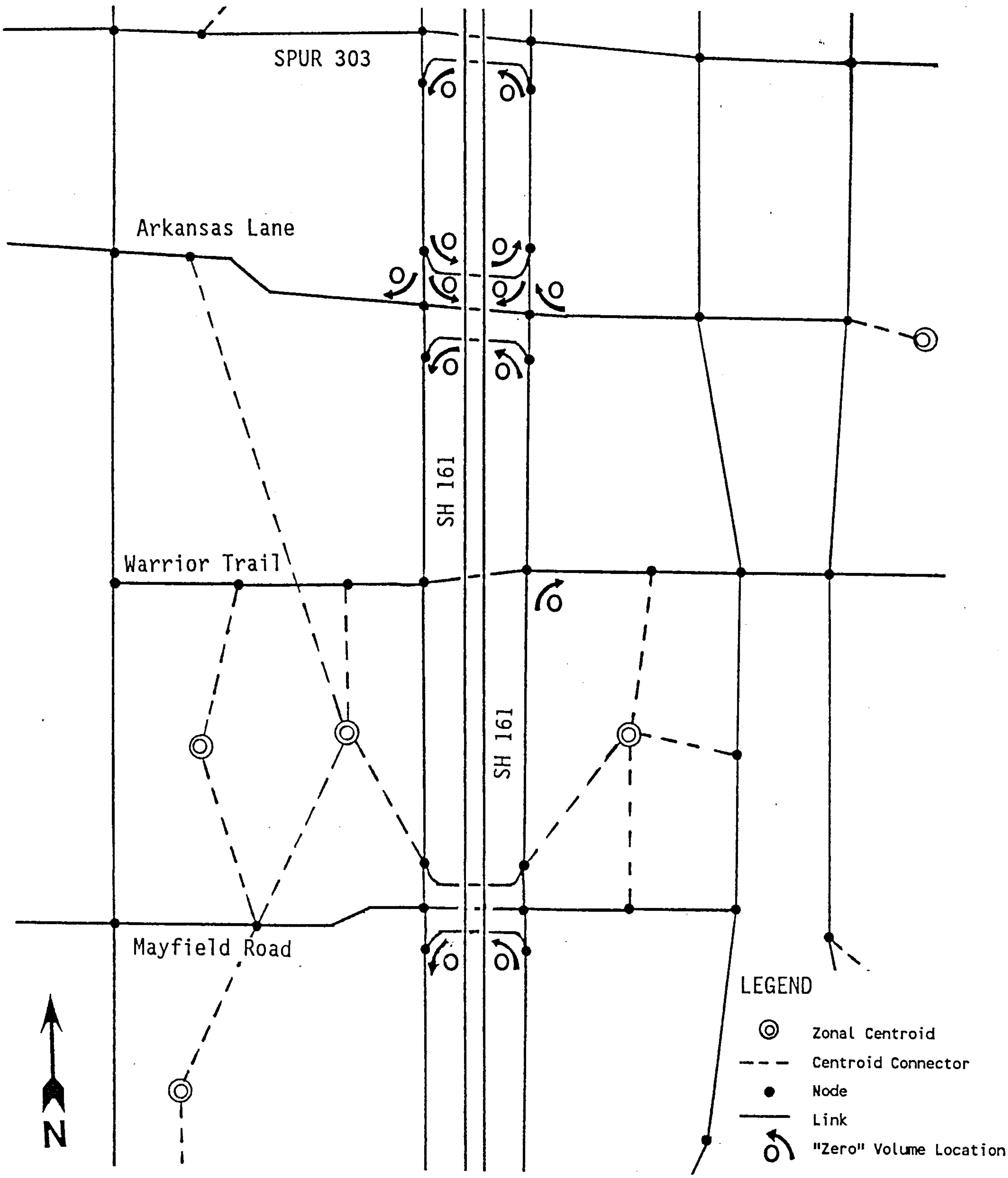



**FIGURE 7 "Zero" Volume Locations from TRANPLAN.**

## Use of Turning Movement Iterative Procedure

The turning movement iterative procedure, a part of the alternative procedure, was performed using a combination of the TRANPLAN assignment results and Corridor Analysis Group results. The turning movement iterative procedures were from NCHRP Report 255. The Lotus program developed by FHWA and modified by COMSIS was used for calibrating the turning movements. Appendix D shows the input and output files from the Lotus program.

Three interchanges (Arkansas Lane, Shady Grove Road, and MacArthur Boulevard) along SH-161 were selected for the turning movement comparisons. The row and column iterations were continued until a difference of less than 10% was obtained. The differences in row totals for all three interchanges were within 10% after the second iteration. The base year traffic data were not available in this study. The following computational procedures were used:

- Step 1: Construct an initial future year turning movement using estimated turn percentages that are derived from the Corridor Analysis Group volume forecast.
- Step 2: Use TRANPLAN assigned link inflow and outflow volumes as the row and the column totals, respectively.
- Step 3: Perform the first row iteration.
- Step 4: Perform the first column iteration.
- Step 5: Repeat row iteration.
- Step 6: Repeat column iteration.

Table 6 shows the results of the turning movements from the three results (Corridor Analysis Group, TRANPLAN, and iterative procedures). The iterative procedures produced closer results to those results produced by the Corridor Analysis Group than the TRANPLAN results.

## Conclusions of SH-161 Case Study

The alternative procedure was evaluated in comparison with the Corridor Analysis Group results. The turning movement differences between the iterative procedures and the

TABLE 6 VOLUME COMPARISONS IN SH-161

| Location (Intersected Street) | | Movements | Corridor Results | TRANPLAN Results | Iterative Results |
|---|---|---|---|---|---|
| S-3 | Arkansas Lane | N-W Turn (R) | 500 | 0 | 477 |
| | | N-E Turn (L) | 600 | 0 | 183 |
| | | S-E Turn (R) | 3400 | 1413 | 1784 |
| | | S-W Turn (L) | 700 | 1322 | 1149 |
| | | E-N Turn (R) | 800 | 0 | 279 |
| | | E-S Turn (L) | 3500 | 1473 | 1615 |
| | | W-S Turn (R) | 1800 | 1575 | 1830 |
| | | W-N Turn (L) | 500 | 0 | 384 |
| | | N-S Thru (T) | 8400 | 6255 | 5679 |
| | | S-N Thru (T) | 7900 | 7981 | 6946 |
| | | E-W Thru (T) | 700 | 759 | 455 |
| | | W-E Thru (T) | 1000 | 1012 | 458 |
| | | N-N Turn (U) | 600 | 0 | 372 |
| | | S-S Turn (U) | 200 | 0 | 179 |
| TOTAL | | | 30600 | 21790 | 21790 |
| C-2 | Shady Grove Road | N-W Turn (R) | 600 | 248 | 359 |
| | | N-E Turn (L) | 400 | 369 | 381 |
| | | S-E Turn (R) | 4700 | 5412 | 5724 |
| | | S-W Turn (L) | 1300 | 718 | 994 |
| | | E-N Turn (R) | 400 | 16 | 509 |
| | | E-S Turn (L) | 4700 | 5365 | 4659 |
| | | W-S Turn (R) | 1000 | 473 | 798 |
| | | W-N Turn (L) | 500 | 566 | 512 |
| | | N-S Thru (T) | 1200 | 504 | 684 |
| | | S-N Thru (T) | 8200 | 8254 | 7696 |
| | | E-W Thru (T) | 1000 | 1496 | 1039 |
| | | W-E Thru (T) | 1300 | 2057 | 1733 |
| | | N-N Turn (U) | 200 | 546 | 139 |
| | | S-S Turn (U) | 200 | 0 | 200 |
| TOTAL | | | 25700 | 26024 | 25427 |
| N-2 | MacArthur Blvd | N-W Turn (R) | 2000 | 0 | 1254 |
| | | N-E Turn (L) | 1100 | 2137 | 1116 |
| | | S-E Turn (R) | 2500 | 1768 | 3015 |
| | | S-W Turn (L) | 3900 | 4614 | 2907 |
| | | E-N Turn (R) | 800 | 497 | 78 |
| | | E-S Turn (L) | 3600 | 4733 | 4405 |
| | | W-S Turn (R) | 3900 | 3641 | 4112 |
| | | W-N Turn (L) | 2000 | 0 | 167 |
| | | N-S Thru (T) | 2200 | 3083 | 2941 |
| | | S-N Thru (T) | 2000 | 0 | 252 |
| | | E-W Thru (T) | 10600 | 5633 | 6086 |
| | | W-E Thru (T) | 8800 | 7269 | 7043 |
| TOTAL | | | 43400 | 33375 | 33376 |

Corridor Analysis Group were less than an average of 30%. The turning movement iterative procedure eliminated the problem "zero" directional volume. The total interchange volume from the iterative procedure was the same as the total of TRANPLAN because the loaded link inflow and outflow volumes from the TRANPLAN were used as input for the row and the column totals, respectively.

The future link volumes from TRANPLAN should be refined before the turning movements are calibrated using the iterative procedure. The refinement procedures were omitted, and only a part of the alternative procedures were applied because of the lack of base year data.

The alternative procedures are recommended for further evaluation by the Corridor Analysis Group.

# CHAPTER IV. TURNING MOVEMENTS

The principal problem in developing project-level forecasts is the need for individual movements at existing or proposed intersections. These intersections include the junctionof two public streets, an access drive with a public street, freeway ramp, terminals with mainlanes and feeder roads, feeder roads and the cross street, and the junction of elements of the on-site circulation of private development.

## NCHRP REPORT 255 PROCEDURES

The User's Manual portion of NCHRP Report 255, Appendix Chapter 8, presents procedures which are (have been) used to develop turning movements. A summary of this chapter (in a modified "Information Mapping (R)" method format) is included as Appendix E of this report. These procedures are classified as follows:

1. Factoring
2. Iterative-directional
3. Iterative-nondirectional
4. T-intersection

The procedures are applicable to an individual intersection. In effect, then, each intersection is considered in isolation and independent of adjacent intersections. This is a significant problem when dealing with urban project design, especially of arterial streets, since a series of intersections need to be designed and operated as a systme.

The following is a critique of the assumptions which are fundamental to the application of each procedure for developing project-level turning movement forecasts from system-level assignments.

### Factoring

Factoring requires the following data:

1. Base year turning movement counts;
2. Base year turning movement assignments; and
3. Future year turning movement assignment.

According to NCHRP Report 255 (page 103), "The assumption used is that the discrepancy between a base year count and a base year assignment is likely to be of the same magnitude in the future year."

The validity of this assumption is extremely questionable. It will not be true for directional movements and movements by time of day in areas which will experience substantial development between the base and future assignment year. This is due to the fact that traffic movements at an intersection are influenced by the pattern of the traffic to and from the development in close proximity to the intersection. Movements at an intersection will be influenced by the following: (1) the number, location and design of the access points serving the development situated adjacent to the intersection; (2) the size and type of development (i.e., residential, industrial commercial); and (3) the building arrangement and site circulation design of development. Furthermore, experience shows that when there are two or more access drives serving a site the movement pattern entering the site is not the same as the movement pattern leaving the site (3).

**Iterative-Directional**

The iterative-directional procedure requires the following input data:

1. Future year directional link volumes; and
2. Either base year counted or assigned directional turning movements or initial estimate of future year directional turning percentages.

If base year turning movement counts are used, it must be assumed that the present pattern of movements will persist over time (7, 105). As discussed above under the factoring procedure, this will not be the case at a location where there is sparse development at present but where substantial development will occur by the future year.

When base year assigned directional movements are used, the assumption must be made that the assigned directional movements in the future year are the same as in the base year. There is no reason to believe that this should be the case for the reasons stated above; site traffic movements through an intersection are highly dependent upon the size, type, and design of the development. Again, traffic engineering experience in signal timing shows that intersection movements change over time, and the change is often substantial. Moreover, the traditional assignmnet procedures are not sufficiently refined to reproduce the detailed traffic patterns associated with specific developments.

The alternative is to make an initial estimate of future year directional turning percentages. While subject to judgment, this is a straightforward analytical problem for an analyst who is experienced with the procedures used in the preparation of site traffic impact studies. The movement volumes contributed by the develoment is close proximity to the intersection is then estimated and added to the background volumes to obtain the forecast of the total volume for each movement. Such a procedure can be expected to provide the best forecasts of turn movement volumes when specific projects are being proposed.

**Iterative-Nondirectional**

This method produce two-way turning volumes given two-way link volumes and an estimate of total turning percentage. It assumes that the "the volume of traffic on a given approach of an intersection is a surrogate for land-use attractions and productions" (7).

There are two deficiencies in this assumption. First, analyses (15, 16) have shown that assigned volumes are not highly sensitive to the trip matrix and that a reasonable geographical distribution of trip ends (productions and attractions) will produce good assignment results. Second, the site design (building arrangement, on-site circulation, and access location and design) of the adjacent land use is known to have substantial effect on traffic patterns in close proximity to the development. System-level assignments cannot simulate the traffic flows resulting from such location specific design details.

**T-Intersections**

Three-way intersections present a simpler mathematical problem than four-way intersections. A unique mathematical soluation can be obtained for nondirectional turns at a three-way intersection. However, it should be noted that the two problems indicated for the iterative-nondirectional method above also apply to three-way intersections.

Directional turning volumes require that one directional volume be known in order to obtain a unique solution. In many cases, the "stem" of a three-way intersection is the access to an adjacent residential development, a commercial office/retail center, or an industrial development. In these cases the directional traffic volumes can be quite accurately estimated using the traffic analysis procedures commonly used in site traffic impact studies. The same procedures are also applicable where two opposing legs of a four-way intersection are the access points to residential, commercial, and/or industrial development.

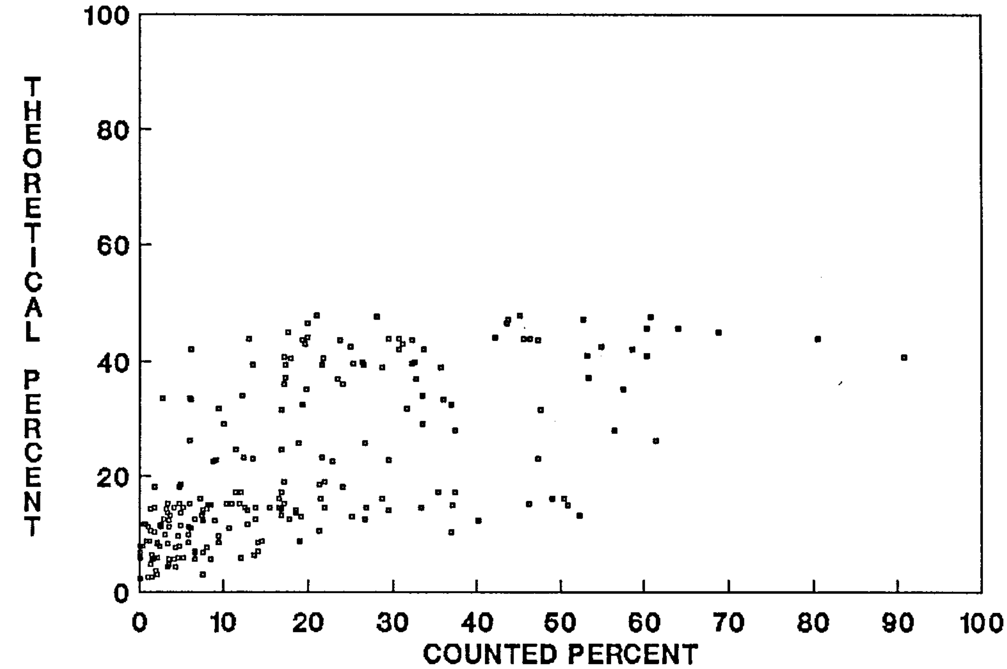
## COMPARISON OF THEORETICAL AND COUNTED TURNING MOVEMENTS

Turning movements were counted at 130 intersections in the cities of Sherman and Denison, Texas. Of these, 56 were 4-way intersections having at least one approach with a traffic volume of at least 1,000 vehicles in the period for which traffic was counted. Manual counts were made for 9 hours: 7:00 a.m. to 10:00 a.m., 11:00 a.m. to 2:00 p.m., and 3:00 p.m. to 6:00 p.m. in 1980. Data were recorded by 15-minute intervals for each intersection leg. For each approach, the left turns, through movement, and right turns were calculated as a percentage of the approach volume.

Theoretical turn proportions were calculated using the procedure developed in Appendix F. Scatter diagrams of the theoretical versus counted turning movements, as a percentage of approach volume, for the 56 intersections are shown in Figures 8, 9, and 10 for left turns, right turns and thru movements, respectively. The diagonal line represents a perfect correspondence between the counted and the theoretical movements as a percentage of the approach volume. Visual inspection indicates that there is a substantial scatter and poor correlation between the theoretical and count data.

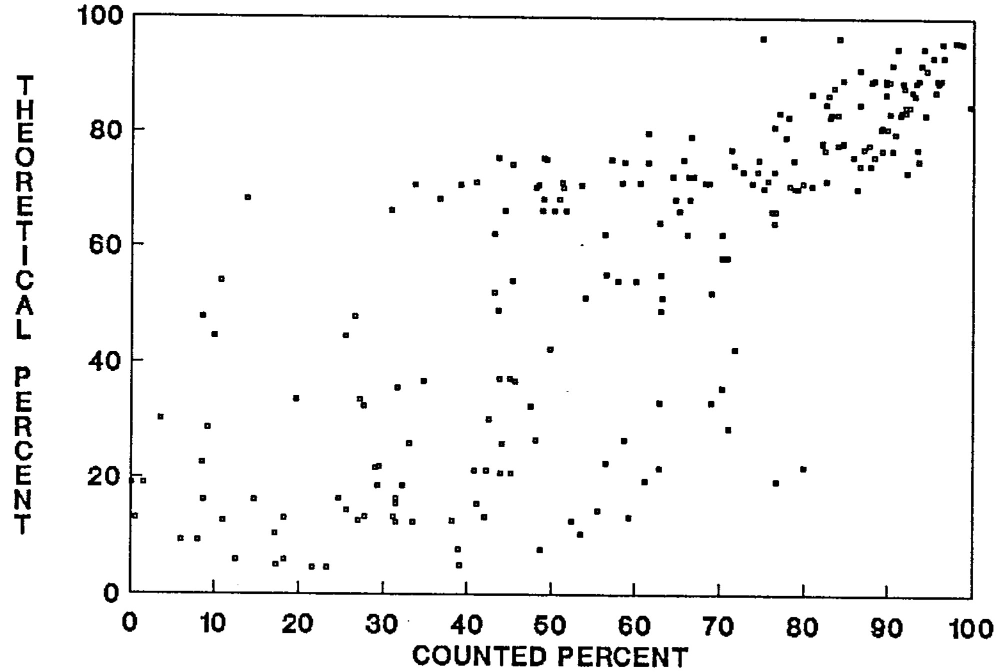
Inspection of the data indicated that the intersection could be stratified into the two following groups:

Group A: Two opposite approaches have moderate volumes (greater than 3,000 vehicles on each approach for the 9-hour count; however, no approach had a volume greater than 10,000) and the other two approaches have low volumes (less than 2,000 vehicles). There were 13 intersections in this group.



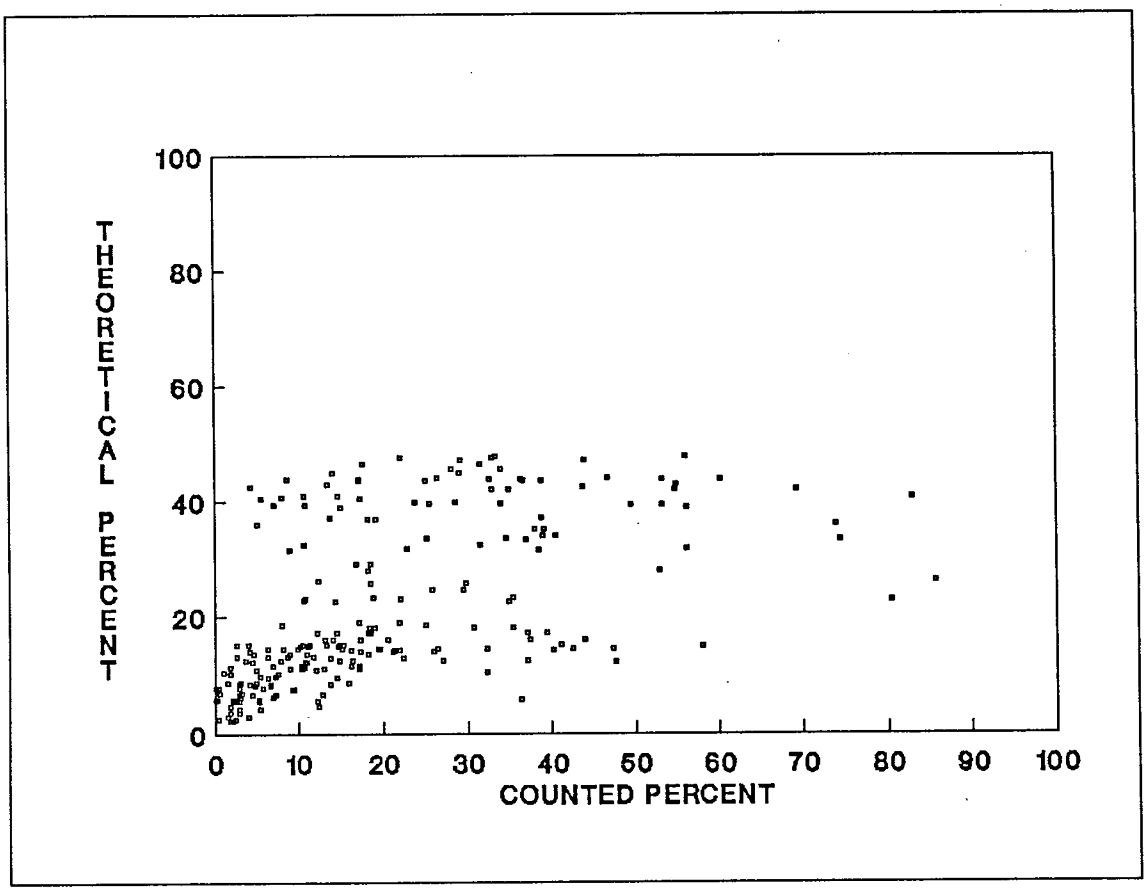

56 Intersections; 224 Movements

**FIGURE 8. Scatter Diagram of Left Turns as a Percentage of Approach Volume (All Intersections).**




56 Intersections; 224 Movements

FIGURE 9. Scatter Diagram of Thru Movements as a Percentage of Approach Volume (All Intersections).




56 Intersections; 224 Movements

FIGURE 10. Scatter Digram of Right Turns as a Percentage of Approach Volume (All Intersections).

Group B: All four approaches have low volumes (less than 2,000 vehicles for the 9-hour count). These 43 intersections can be further classified as:

B-1: The volume on two approaches was relatively high (1,200 to 1,800) compared to the other two opposing approaches (typically 200 to 800).

B-2: The volumes on all four approaches were low and similar (typically 100 to 700 vehicles for the 9 counted hours).

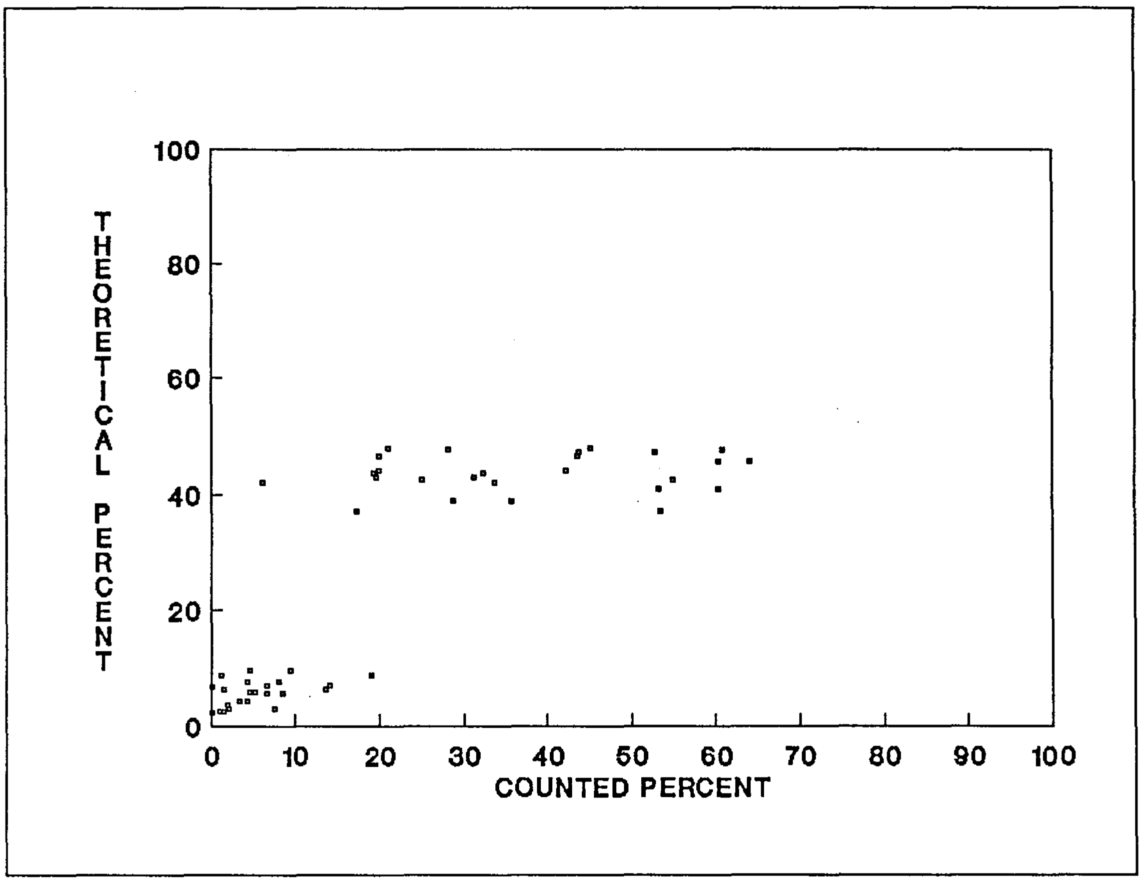
B-3: Three of the approaches had similar volumes (typically about 800 to 1,000 vehicles) while the fourth had a small volume (typically less than 400).

B-4: Some pattern of approach volumes other than the above.

Figures 11, 12, and 13 show the scatter diagrams for the Group A intersections: those with moderate volumes on two opposing approaches and low volumes on the other two opposing approaches. Visual inspection indicates two distinct groupings. This is due to the fact that thru movements are a very high percentage of the approach volume on the major (higher volume) approaches. Consequently, left and right turns constitute a small percentage of the approach volume. The reverse is true for the minor (low volume) approaches of these intersections. This is clearly observable when the major and minor apoproaches are plotted separately (see Figures 14 thru 17). Since the left and right turns have similar patterns, they have been combined in one scatter diagram (Figure 14 for the major approaches and Figure 16 for the minor approaches).

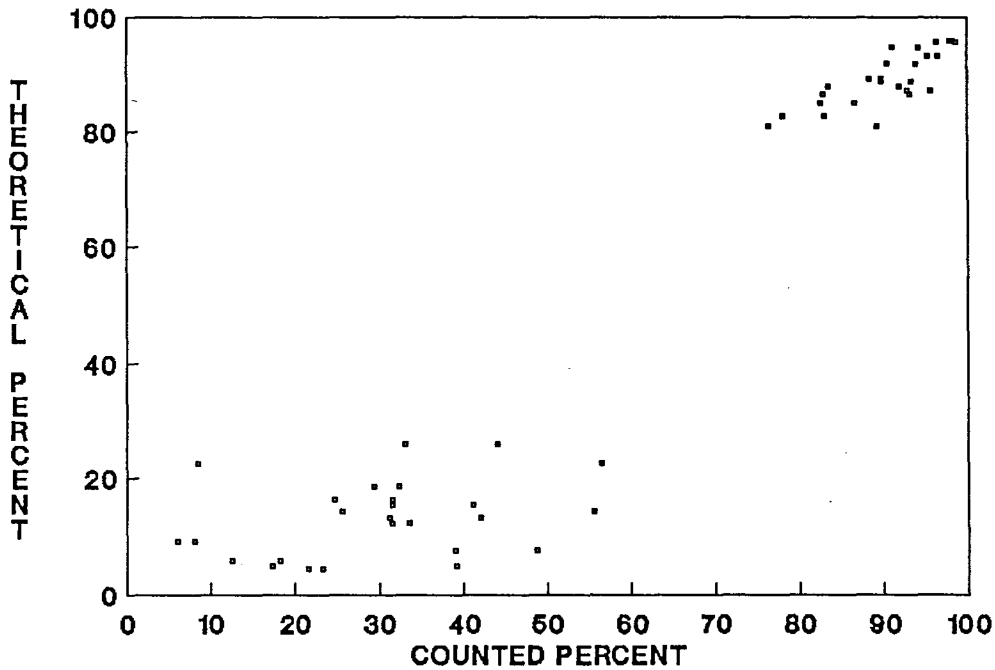
This difference in percent movements is to be expected. Even though the left- and/or right-turn volumes may be substantial, they must be a relatively small percentage of the larger approach volume. This pattern of turn movements is typically of intersections of arterial streets with collector/distributor streets.

Plots of the Group B intersections are given in Figures 18, 19, and 20 for left turns, thru movements, and right turns respectively. The data show extensive scatter and no particular pattern is evident. A more detailed review of the raw data indicated that the movements as a percentage of approach volume show substantial variability at low volume intersections where the approach volumes are similar. Thru movements range from about 35% to near 80%; left and right turns both range from less than 10% to more than 30%.



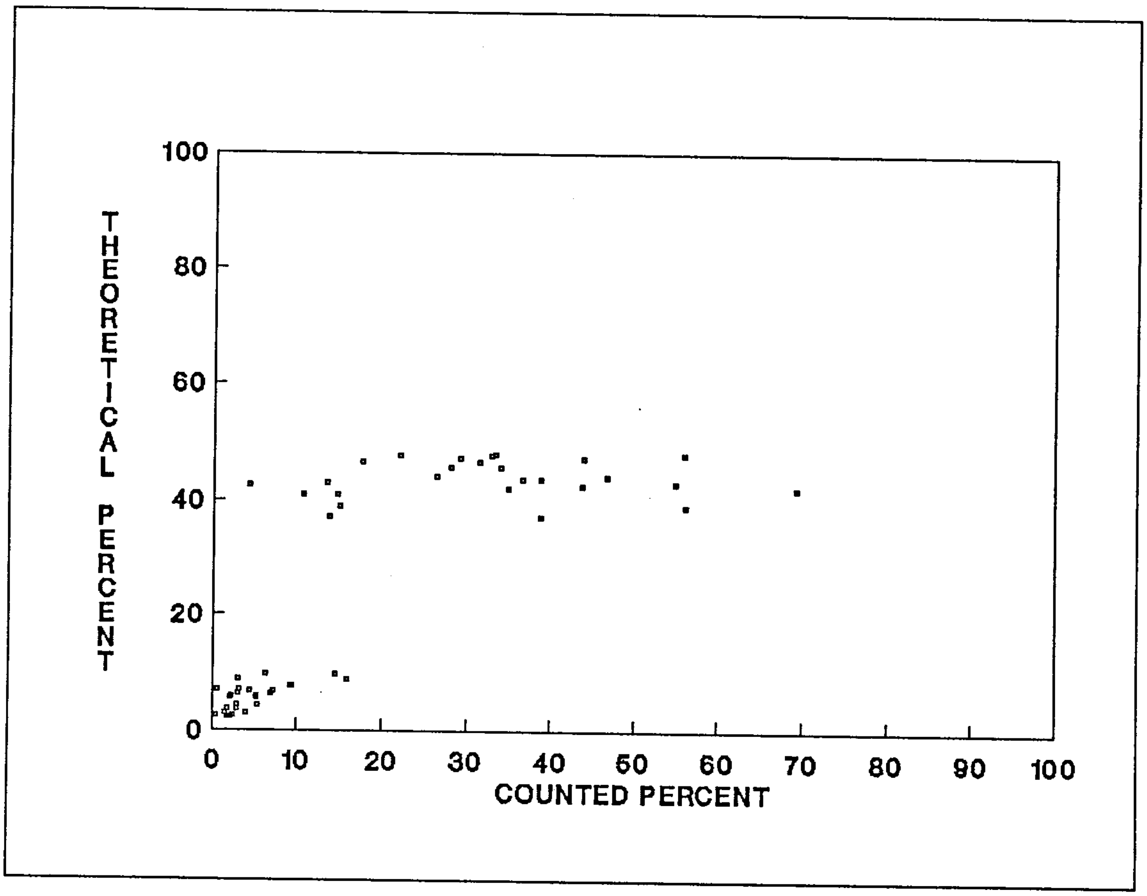

Higher Volume Intersections: 13 Intersections; 52 Movements

FIGURE 11 Scatter Diagram of Left Turns as a Percentage of Approach Volume (Higher Volume Intersections).



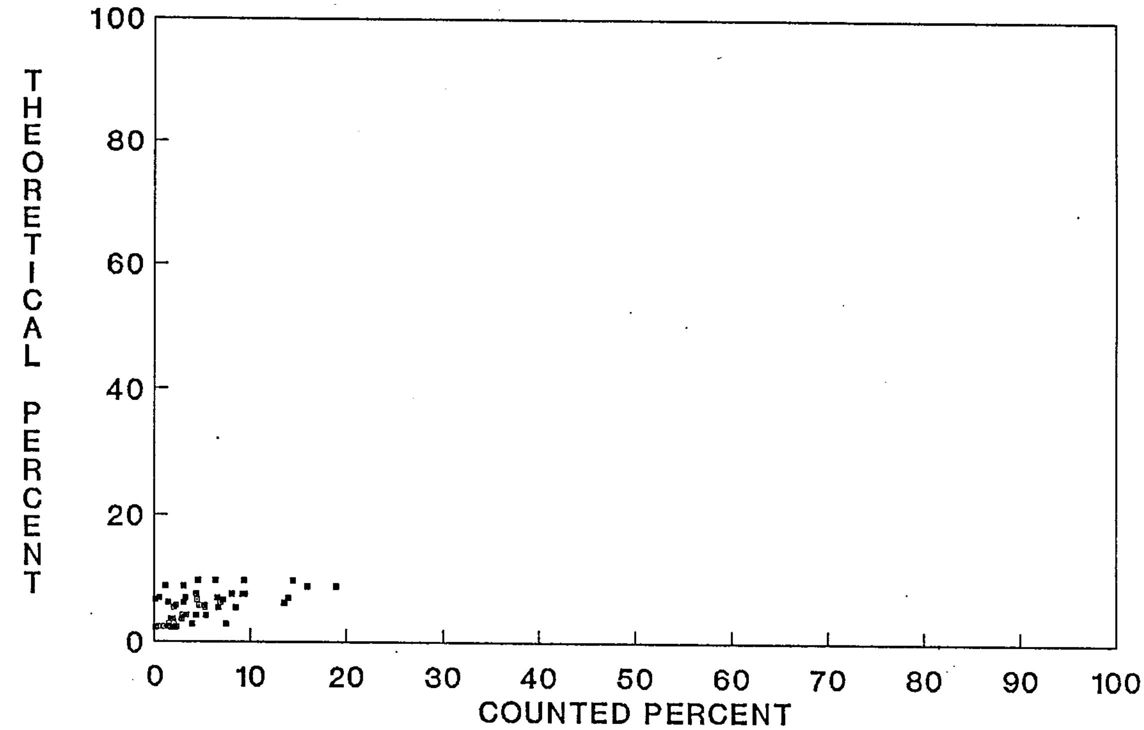

Higher Volume Intersections: 13 Intersections; 52 Movements

FIGURE 12 Scatter Diagram of Through Movements as a Percentage of Approach Volume (Higher Volume Intersections).



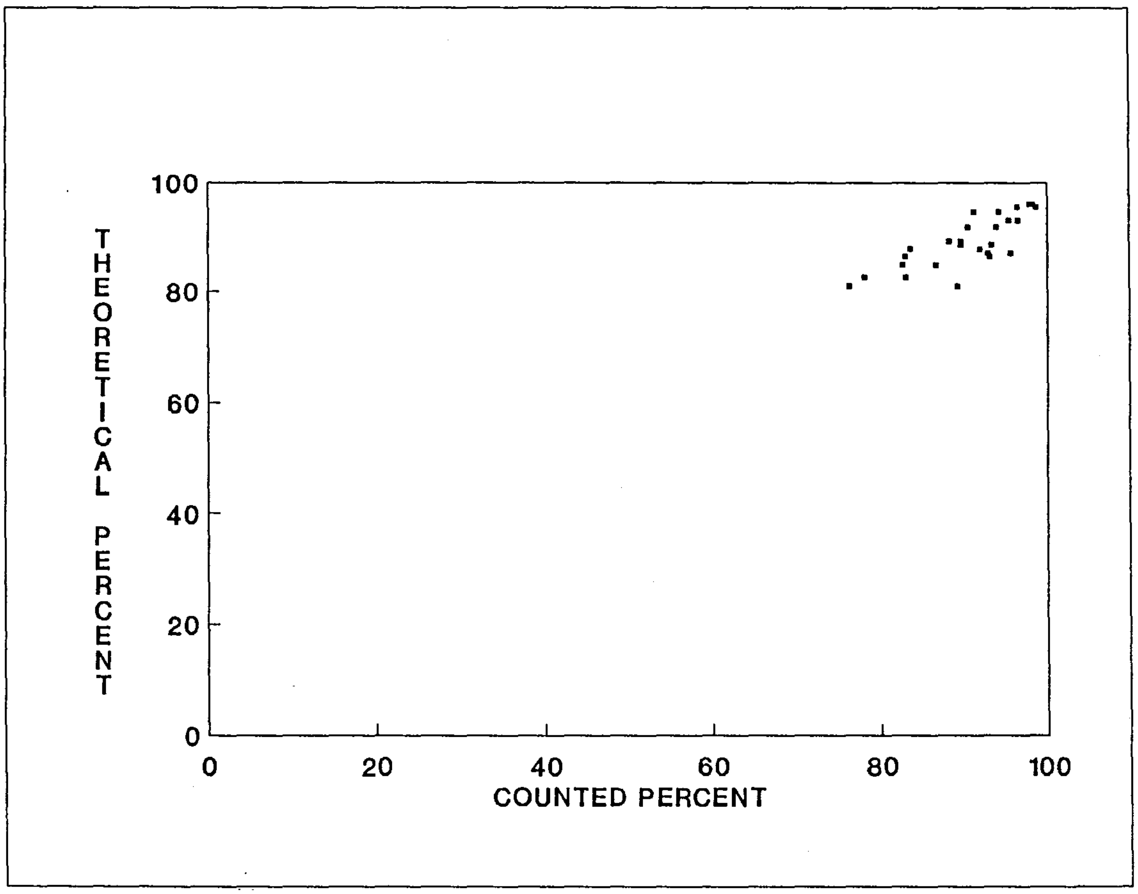

Higher Volume Intersections: 13 Intersections; 52 Movements

FIGURE 13 Scatter Diagram of Right Turns as a Percentage of Approach Volume (Higher Volume Intersections).



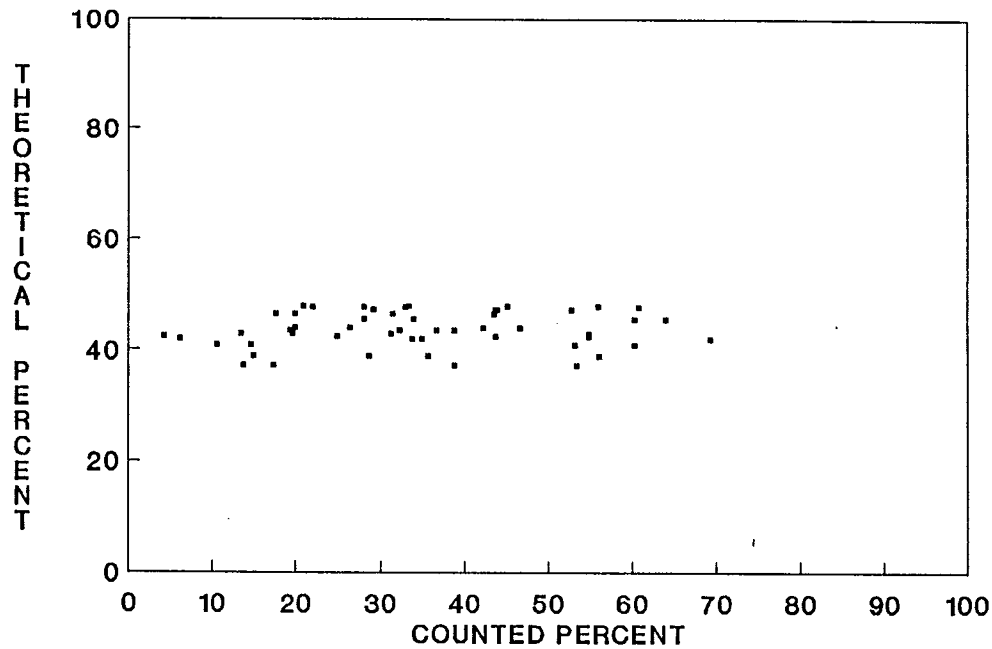

13 Intersections; 52 Movements

FIGURE 14 Scatter Diagram of Left and Right Turns as a Percentage of Approach Volume for the Higher Volume Approaches of Group A (Higher Volume) Intersections.



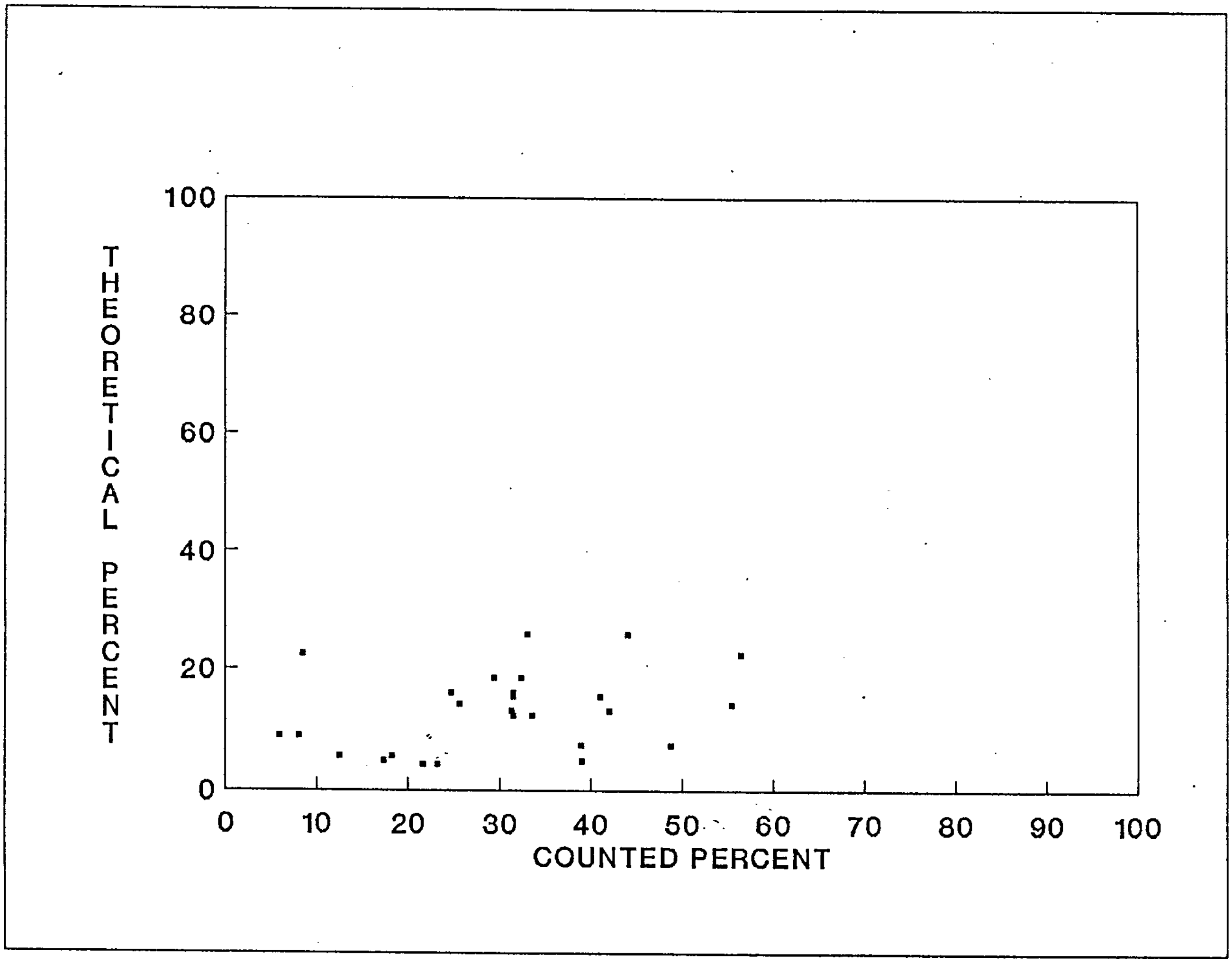

13 Intersections; 26 Movements

FIGURE 15 Scatter Diagram of Thru Movements as a Percentage of Approach Volume on Higher Volume Approaches of Group A (Higher Volume) Intersections.



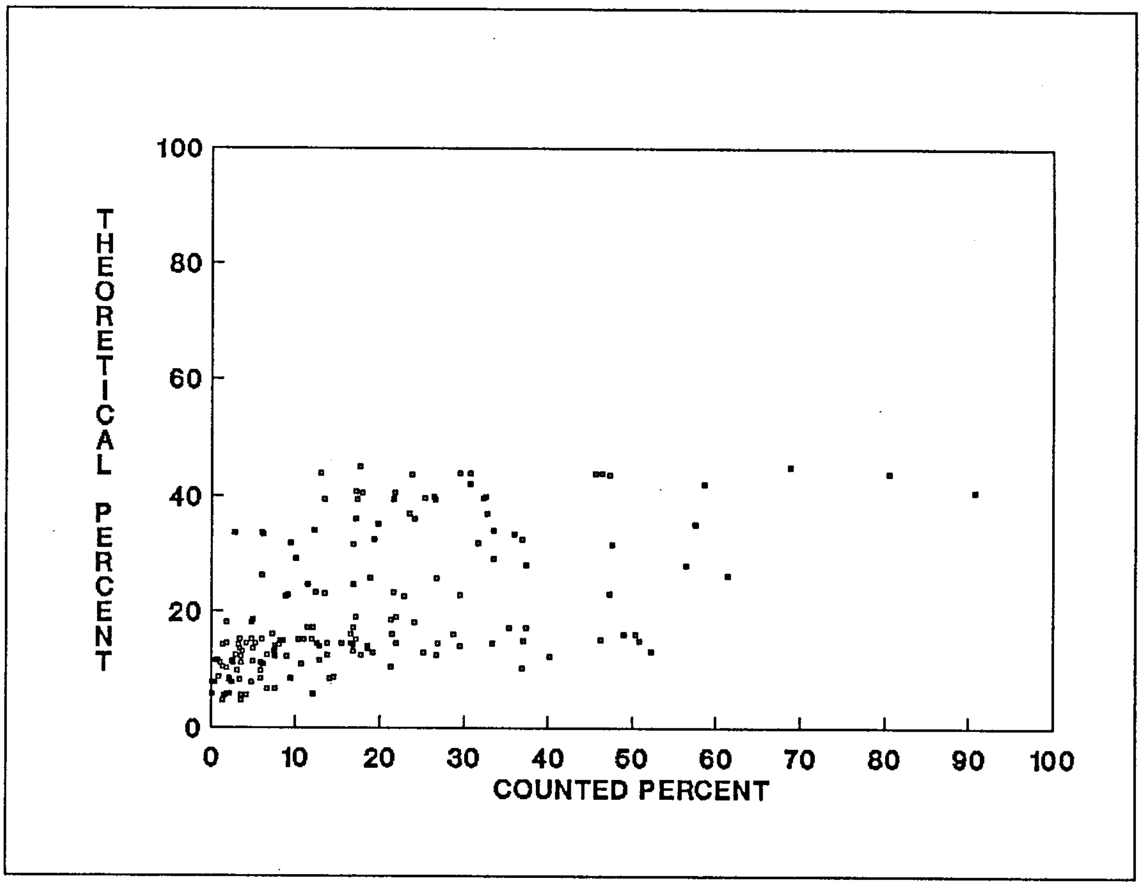

13 Intersections; 52 Movements

FIGURE 16 Scatter Diagram of Left and Right Turns as a Percentage of Approach Volume on Lower Volume Approaches of Group A (Higher Volume) Intersections.




13 Intersections; 26 Movements

**FIGURE 17 Scatter Diagram of Thru Movements as a Percentage of Approach Volume on Lower Volume Approaches of Group A (Higher Volume) Intersections.**




Group B -- Low Volume Intersections: 43 Intersection, 172 Movements

FIGURE 18 Scatter Diagram of Left Turns as a Percentage of the Approach Volume (Low Volume Intersections).

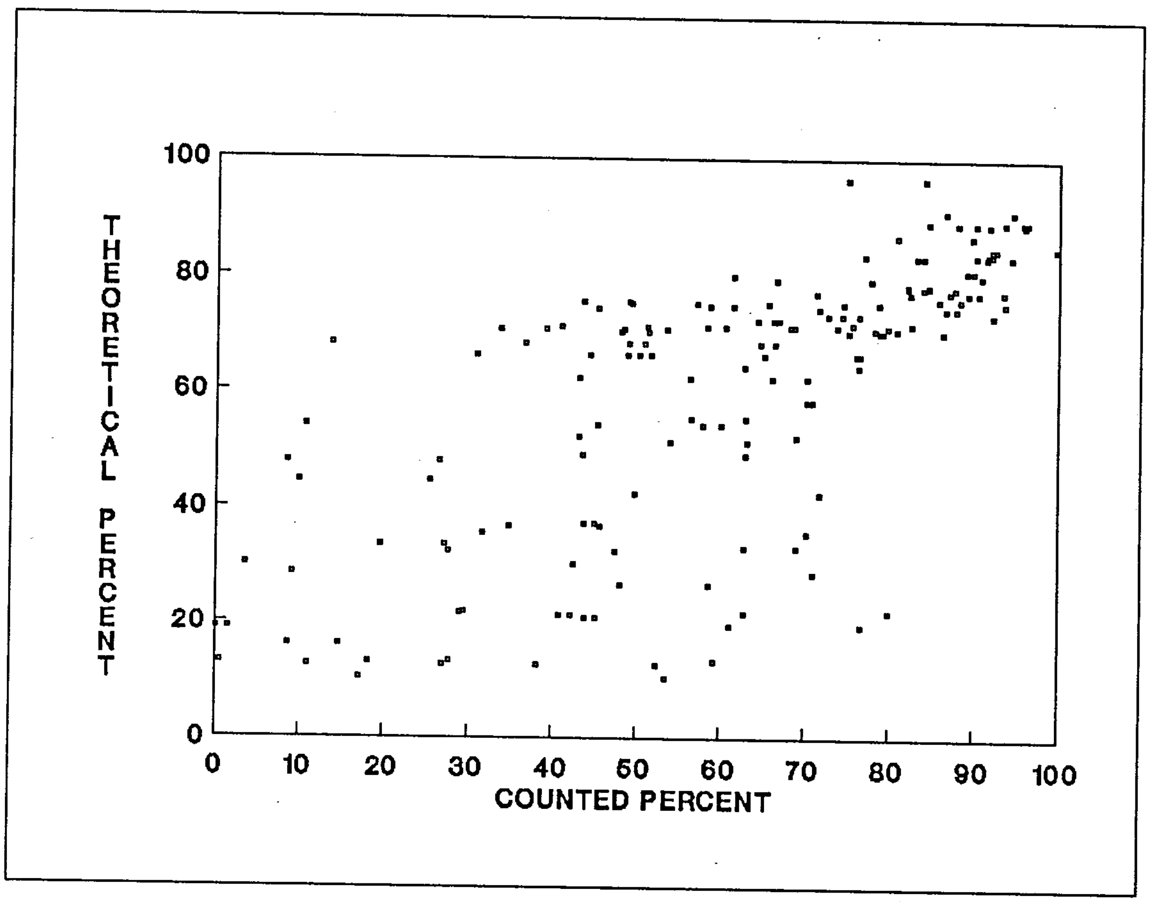



FIGURE 19 Scatter Diagram of Thru Movement as a Percentage of the Approach Volume (Low Volume Intersections).

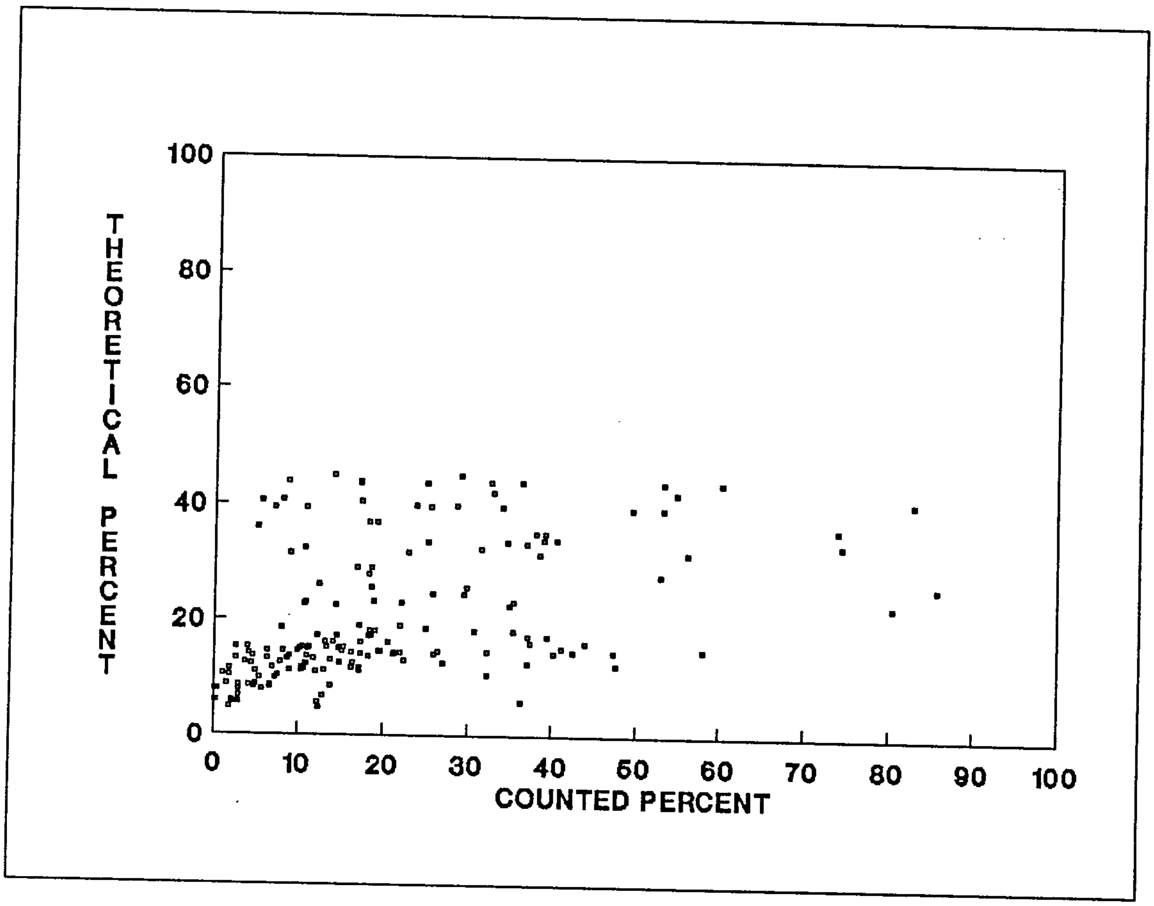



FIGURE 20 Scatter Diagram of Right Turns as a Percentage of the Approach Volume (Low Volume Intersections).

While the four general patterns (B-1 thru B-4) identified above are apparent from the raw data, subdivision into these groups for analysis did not appear to be worthwhile for the purposes of this study due to the limited number of intersections in each of the subgroups.

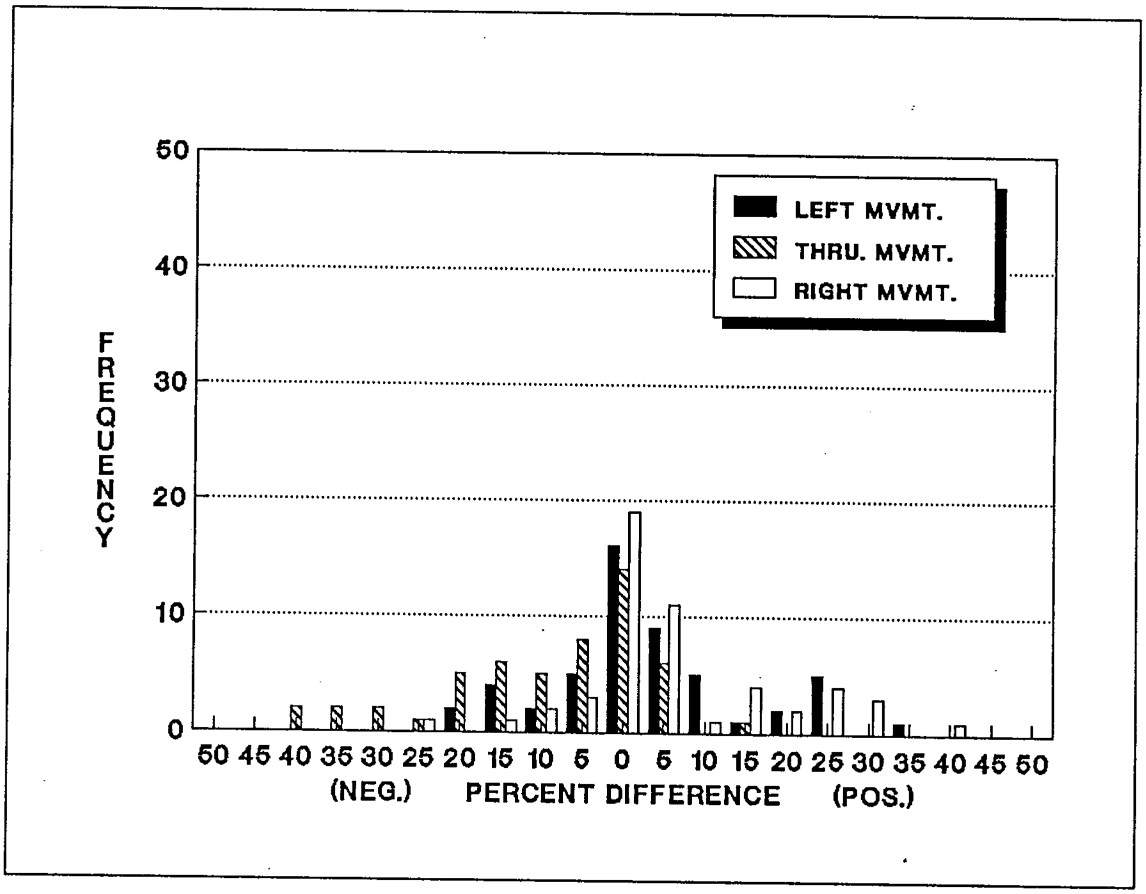
Figure 21 shows the distribution of the differences between the theoretical and counted movements as a percent of approach volume (percent theoretical minus percent by count) for the 13 higher volume (Group A) intersections. Hence, negative values indicate an underestimate by the procedure for calculating the theoretical percentage. The differences appear to be more or less symmetrically distributed. However, close inspection indicates that the differences in the thru movements are skewed to positive differences. Thus, the theoretical procedure tended to underestimate the thru movement and overestimate left and right turns as a percent of approach volume.

Figure 22 shows the distribution of the difference in the theoretical and observed turn percentages. The modal (most frequent) difference for thru movements is a minus 10%, for left and right turns it is plus 5%. This suggests that theoretical procedure tends to underestimate thru movement percentages and overestimate turn movements where intersection approach volumes are very small.

**Statistical Analysis**

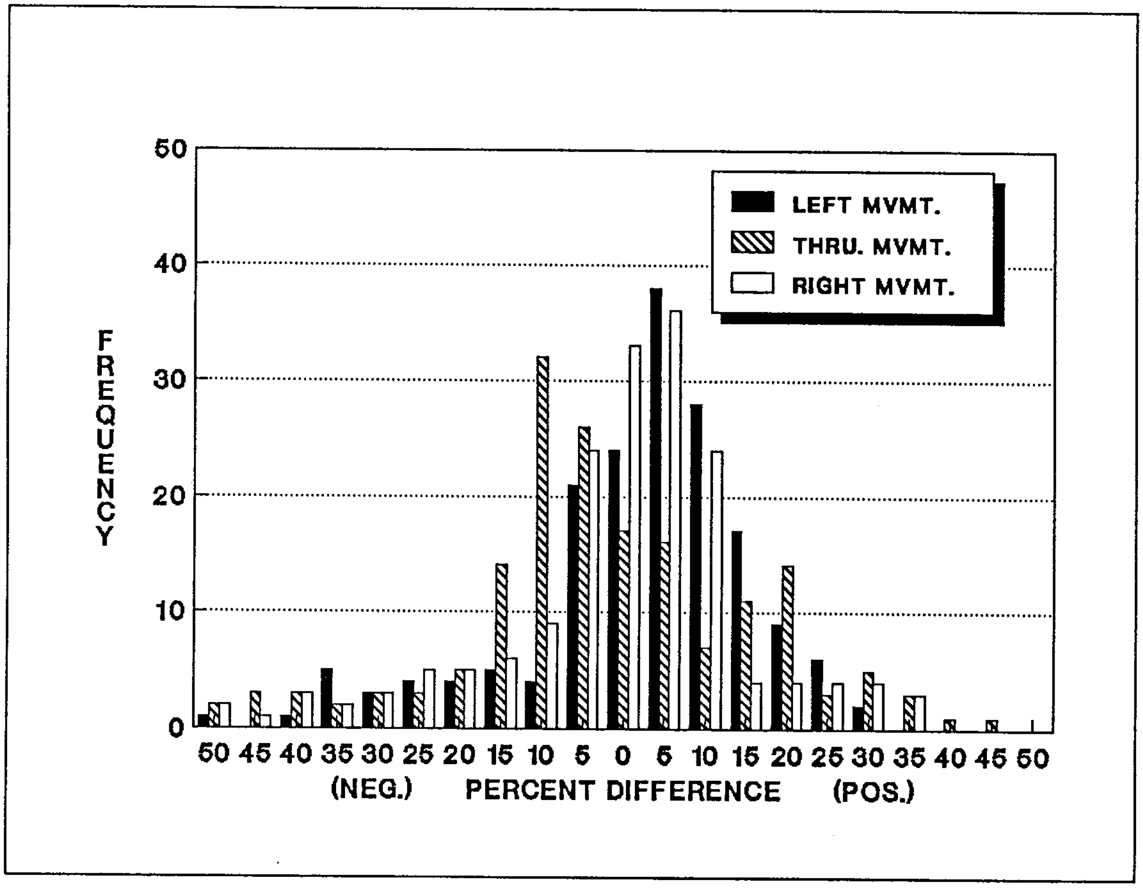
F-tests at the 10% significance level were performed to determine if the variances of the theoretical and observed percent left turns, thru movements and right turns are significantly different.

The statistical data are summarized in Table 7. The numerical value of the variance of the counted volume is larger than the theoretical values in all cases. This is to be expected since the "real world" will experience some diversity, while the theoretical procedure yields a unique solution for a given set of approach volumes. In all but two cases, the alternate hypothesis was accepted: there is statistical evidence that the difference in the variances is significant.




13 Intersections; 52 Movements

FIGURE 21 Histogram of Difference (Theoretical Minus Count) in Intersection Movements as a Percentage of Approach Volume at Higher Volume Intersections.




43 Intersections; 172 Movements

FIGURE 22 Histogram of Difference (Theoretical Minus Count) in Intersection Movements as a Percentage of Approach Volume at Low Volume Intersections.

TABLE 7 F-TEST FOR DIFFERENCE IN VARIANCES IN THEORETICAL AND OBSERVED MOVEMENTS AS A PERCENT OF APPROACH VOLUME

| Movement | Variance: Observed | Variance: Theoretical | F Calculated | F critical[1]: Lower | F critical[1]: Upper | Accept $H_a$ ? [2] |
|---|---|---|---|---|---|---|
| **Group A Intersections, Major Approaches, n = 26, movements** | | | | | | |
| left turn | 22.3 | 5.4 | 4.16 | 0.47 | 2.10 | yes |
| thru | 36.2 | 21.6 | 1.68 | 0.47 | 2.10 | no |
| right turn | 14.7 | 5.4 | 2.73 | 0.47 | 2.10 | yes |
| **Group A Intersections, Major Approaches, n = 26, movements** | | | | | | |
| left turn | 261.1 | 10.4 | 25.17 | 0.47 | 2.10 | yes |
| thru | 179.0 | 41.9 | 4.28 | 0.47 | 2.10 | yes |
| right turn | 251.2 | 10.4 | 24.21 | 0.47 | 2.10 | yes |
| **Group B Intersections, Major Approaches, n = 26, movements** | | | | | | |
| left turn | 278 | 134 | 2.07 | 0.74 | 1.35 | yes |
| thru | 610 | 551 | 1.11 | 0.74 | 1.35 | no |
| right turn | 299 | 134 | 2.23 | 0.74 | 1.35 | yes |

(1) 10% significance level

(2) Alternate Hypothesis, $H_a$: There is a significant difference in the variances of the counted and theoretical turn volumes.

Based upon the evaluation of the variances, it is concluded that the theoretical procedure will tend to underestimate the variance in turn volumes.

The mean percent turns calculated from the traffic counts and the percent turns estimated by the theoretical procedure are given in Table 8. The theoretical means agree closely with the observed values for the major approaches of the Group A (high volume) intersections. The difference is less than one percent for left (0.5%) and right turns (0.8%)

TABLE 8 MEAN THEORETICAL AND OBSERVED TURNS AS A PERCENTAGE OF APPROACH VOLUME

| Movement | Mean Percent Turns | | |
|---|---|---|---|
| | Observed | Theoretical | Difference |
| **Group A Intersections, Major Approaches, n = 26 movements** | | | |
| left turn | 5.0 | 5.5 | 0.5 |
| thru movement | 0.3 | 89.1 | -1.2 |
| right turn | 4.7 | 5.5 | 0.8 |
| **Group A Intersections, Minor Approaches, n = 26 movements** | | | |
| left turn | 37.3 | 43.5 | 6.2 |
| thru movement | 30.2 | 13.0 | -16.2 |
| right turn | 32.5 | 43.5 | 11.0 |
| **Group B Intersections, n = 172 movements** | | | |
| left turn | 18.1 | 20.1 | 2.0 |
| thru movement | 61.4 | 60.0 | -1.4 |
| right turn | 20.6 | 20.1 | -0.5 |

and is only slightly more than one percent (1.2%) for thru movements. However, there is very poor agreement for the minor approaches.

The theoretical and observed percent turns for the Group B (low volume) intersections also agree reasonably well. However, in view of the considerable variation from intersection to intersection (see Figures 18, 19, and 20), the potential error at a specific intersection is high.

The paired t-test was applied to determine if there is a significant difference between the mean percent turns estimated by the theoretical procedure and the observed percent turns. This test, rather than the standard t-test, was used since the observed and theoretical data sets are not independent. Rather, the theoretical percent turns are a function of the approach volumes at a particular intersection. The paired t-test statistics are presented in Table 9.

The alternate hypothesis was rejected for the major approaches at high volume (Group A) intersections (there is a significant difference between the theoretical and observed mean percent turns). Therefore it can be concluded that the mean percent turns estimated by the theoretical procedure could be the same as the observed mean percent turns. Inspection of Figures 14 and 15 shows that there is very little scatter in these data points. Thus, it appears that the theoretical procedure produces a reliable estimate of turning movement percentages for the major approaches of intersections where two opposing approaches have high traffic volumes and the other two opposing approaches have low volumes.

However, the two following limitations should be noted. First, this conclusion applies to turning movements over the high traffic hours of the day. Since most of the daily traffic in an urban area occurs during the hours for which traffic count data were collected, it might be assumed that the theoretical percent turns are applicable to the 24-hour period. However, there is no evidence to suggest that the procedure provides reliable estimates of percent turns during specific times of the day (e.g., a.m. or p.m. peak hours).

TABLE 9 SUMMARY OF STATISTICS FOR THE PAIRED t-TEST FOR DIFFERENCES IN THEORETICAL AND COUNTED MOVEMENTS AS A PERCENTAGE OF APPROACH VOLUME

| | | | t Statistic | | Accept |
|---|---|---|---|---|---|
| Movement | d | $S_d$ | Calculated | Critical [1] | $H_a$? [2] |
| **Group A Intersections, Major Approaches, n = 26 movements** | | | | | |
| left turn | 0.47 | 4.26 | 0.56 | +1.71 | no |
| thru movement | -1.20 | 3.77 | -1.62 | +1.71 | no |
| right turn | 0.76 | 2.93 | 1.32 | +1.71 | no |
| **Group A Intersections, Minor Approaches, n = 26 movements** | | | | | |
| left turn | 3.59 | 12.56 | 3.49 | +1.71 | yes |
| thru movement | -9.31 | 22.59 | -2.10 | +1.71 | yes |
| right turn | 1.92 | 19.24 | 0.51 | +1.71 | no |
| **Group B Intersections, n = 172 movements** | | | | | |
| left turn | 4.49 | 17.47 | 3.37 | +1.645 | yes |
| thru movement | -1.30 | 23.49 | -0.73 | +1.645 | no |
| right turn | -2.97 | 21.27 | -1.83 | +1.645 | yes |

(1) 10% significance level

(2) Alternate hypothesis, $H_a$: There is a significant difference in the mean percent turns (turn volume as a percentage of approach volume) estimated by the theoretical procedure and that calculated from ground counts.

Second, count data were available for a limited number of intersections having a moderate volume on two opposing approaches in a single urban area. Additional data at several intersections in a number of urban areas in order to determine if the theoretical procedure is generally applicable.

The variation in the difference between the theoretical and observed percent turns is relatively small (standard deviations of 4.26%, 3.27%, and 2.93% for left, thru, and right turn movements, respectively). These values suggest that the magnitude of the difference which might be expected between the observed and theoretical values is about 3% or 4%. The confidence with which a turning movement percentage at an individual intersection might be estimated is as follows:

| Error (Theoretical % Turns Minus True % Turns) | Approximate Confidence Level |
|---|---|
| ±4% | 70% |
| ±3% | 55% |
| ±2% | 40% |

Thus, if the theoretical percent turns is, say, 6%, there is about a 40% probability that the actual turn percentage is between 4% and 8%, or the probability that the actual percentage is less than 4% is approximately 30%. There is also about a 30% chance that the actual percent turns is more than 8%.

Analyses of the remaining portions of the data set indicate that the theoretical procedure does not provide reliable estimates of turn movements as a percent of approach volume for low volume intersections or for the low volume approaches at high volume intersections. In each case (Group B minor approaches and Group B intersections), the alternate hypothesis (there is a significant difference in the means) is accepted.

Furthermore, the standard deviations of the differences are extremely large in all cases. The smallest value is 12.56% and the largest is over 23%. Consequently, the estimated percent turns of an individual intersection would be extremely unreliable.

**Summary of Conclusions**

The analyses indicate that the theoretical procedure does not yield good estimates of intersection turning movements at intersections where all approaches have low traffic volumes. Further, it does not provide good estimates for the low volume approaches of intersections at which two opposing approaches have high volumes and the other two opposing approaches have low volumes.

The theoretical procedure did yield good estimates of the percent turns for the major approaches of intersections at which two opposing approaches have high traffic volumes and the other two have low volumes. This suggests that the theoretical procedure may be applicable to intersections where at least two of the four approaches have high traffic volumes. Additional research is essential to verify the results obtained with the very limited data set which is available.

From a practical application standpoint, the need to forecast turn percentages, and then turn volumes, involves intersections at which high traffic volumes are expected on at least two approaches. There is little need to forecast individual movement at very low volume intersections because the individual turn volumes will not affect the design. The intersection geometries will be controlled by physical turning characteristics of the design vehicle. Capacity will not be an issue since an intersection with minimum physical characteristics can accommodate substantial volumes. And finally, intersections with very low volumes on all approaches are local street/collector street connectors which are a function of the subdivision or site development design. Even the intersection of two collector/distributor facilities, site distance, and design vehicle characteristics, not the volume of the various movements, will be the controlling factor.

**Recommendations for Further Analyses**

The theoretical procedure appears to have promise for estimating turning movements at high volume intersections. In order to validate the procedure and to identify the range of volumes over which it is valid, it is recommended that turning movement counts be made at a number of intersections. The following list is in order of priority for data collection and analysis:

1. All four approaches to the intersection are known to have high ADTs as well as high volumes during the a.m. and p.m. peak periods. A nondirectional ADT of at least 40,000 vpd on each of the four legs of the intersection is a suggested minimum criterion for selection.
2. Two opposing approaches are known to have high ADTs as well as high volumes in the a.m. and p.m. peak periods. An ADT of at least 40,000 vpd on these two legs of the intersection is suggested. The other two approaches

should have moderate volumes. An ADT of at least 5,000 vpd on each of the two lower volume approaches is suggested as a selection criterion.

3. All four approaches have similar volumes but of a lower magnitude than (1) above. The suggested selection criterion is that the ADT on each of the four intersection legs be between 20,000 and 30,000 vpd.

The following recommendations are made relative to the data collection:

1. The manual turning movement counts should be made for the period 6 a.m. to at least 8 p.m.
2. The data should be summarized by 15-minute intervals. This will permit identification of the highest volume 60-minute interval at each intersection during the a.m. and p.m. peak periods. Thus the theoretical turn percentages can be compared to the counted percentages for the a.m. peak hours, for other selected hours of the day, and for the total count period.
3. In order to evaluate transferability of the results, data should be collected in at least three different urban areas.
4. In order to provide a degree of statistical reliability, data should be collected for at least 10 (preferably at least 30) intersections in each of the volume categories in each city. For example, at 30 intersections where all approaches are known to have high volumes (see (1) above) counts should be taken (i.e., 10 intersections x 3 urban areas). If all three volume categories are to be evaluated, 90 intersections would need to be counted (i.e., 3 categories x 10 intersections in each category x 3 urban areas).

# CHAPTER V. RESTRAINT ASSIGNMENT USING EQUALIZED V/C RATIOS

Existing capacity restraint assignment procedures provide excellent results for evaluating system-level alternatives and for analyzing transportation system plans. However, refinement of the assignment results, such as that performed by the Corridor Analysis Group of the Transportation Planning Section (D-10P), is essential for project-level planning. Such procedures are manual and therefore time-consuming.

Their research study developed and evaluated a computerized process which equalizes the V/C ratios on competing routes. The logic of such an approach is as follows: In a very detailed network there are a large number of possible paths between two points which are some distance apart. Several of these possible paths have similar total impedances (total centroid-to-centroid travel time). Each of the similar paths should accommodate some of the trips. And the distribution of traffic on these paths should result in V/C ratios which are equal or nearly equal.

Such a procedure should more closely reflect actual trip-making characteristics when the coded network is in such detail that it has, or nearly has, a one-to-one correspondence to the actual street system. Therefore, the procedure equalizing V/C ratios should produce more realistic turning movement volumes.

## STUDY PROCEDURES

Testing of the assignment procedures to equalize the V/C ratios on competing routes involved the following elements:

1. Formulation of the procedure
2. Development of the prototype microcomputer software
3. Selection and coding of a test network
4. Analysis of the results

### Formulation of Procedures

The procedures for equalizing the V/C ratios on competing routes involve two elements. The first is to be able to identify the links which comprise competing routes. This was easily accomplished since the TRANPLAN package utilizes a two-digit field for link classification. Different numbers in this field were used to identify the various links in the different competing routes for the purposes of testing and evaluating the concept of equalizing V/C ratios. If the procedure was found to be effective, the TRANPLAN package would be modified to establish a unique field for identifying competing routes. The present link classification field would then be used for the traditional functional classification purposes.

The second element is to determine the impedance adjustment function. It was hypothesized that this function should have the properties indicated in Figure 23. If the V/C ratios of a link are equal to the average V/C for given competing routes, the adjusted impedance should be the same as the previous impedance. If the link V/C is greater than or less than average, the impedance should be increased. Further, the magnitude of the adjustment should increase as the ratio of the link V/C to the average V/C becomes more distant from 1.0.

**Development of Software**

The existing TRANPLAN package was modified to incorporate a technique to equalize the V/C ratios. This involved development of two subroutines. The first was for calculating the average V/C ratios for all links on competing routes. The second subroutine calculated the adjusted link impedances. The relationship between the subroutines and the main TRANPLAN program is indicated in Figure 24. Figure 25 shows the subroutine structure for calculating the average V/C ratio. The procedure for modifying the existing HLOD5 subroutine in TRANPLAN is shown in Figure 26. Figure 25 shows the existing BPR formula used to update the impedance on those links which are not competing routes within the project-level area and on links outside of the project area.

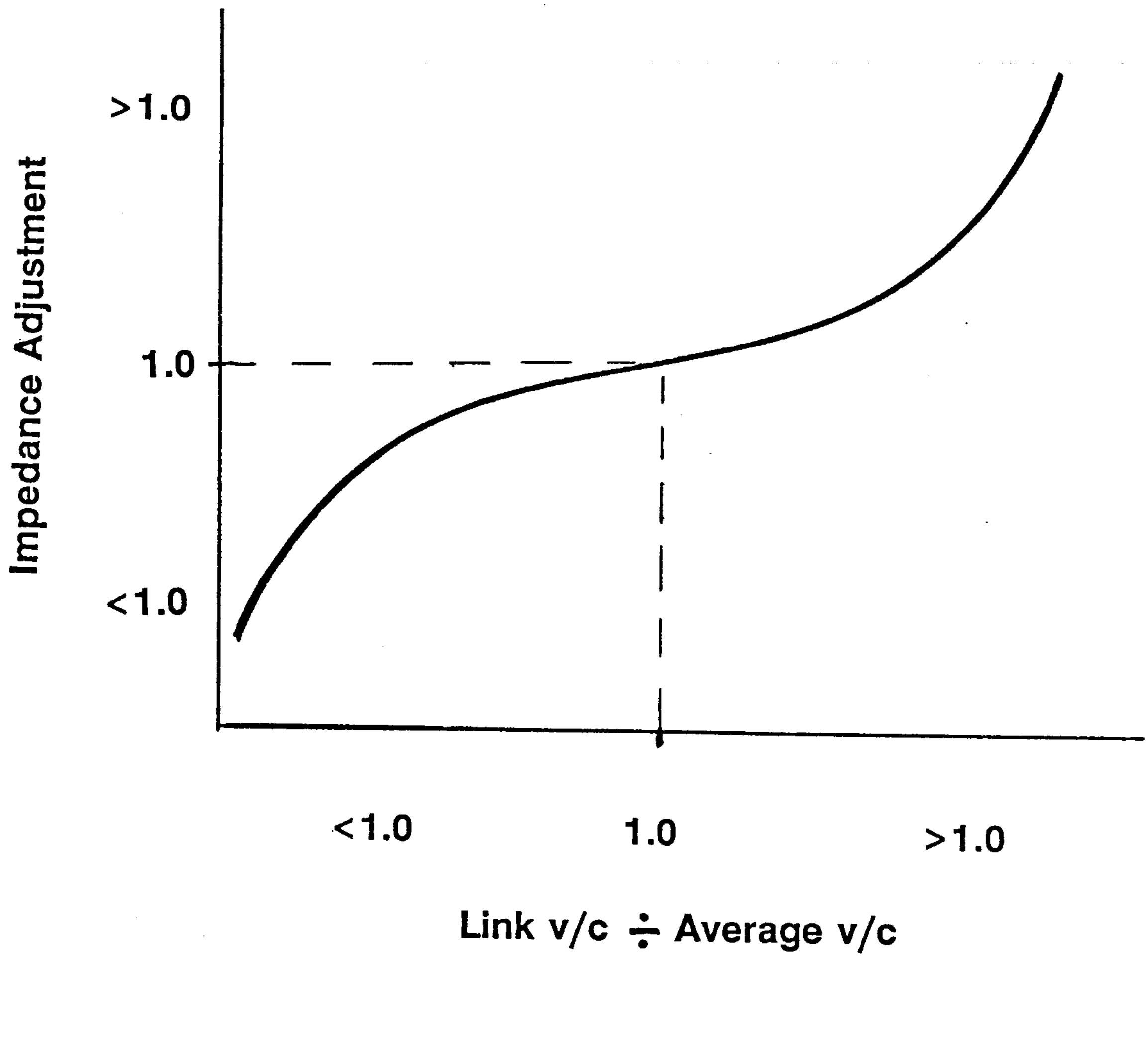
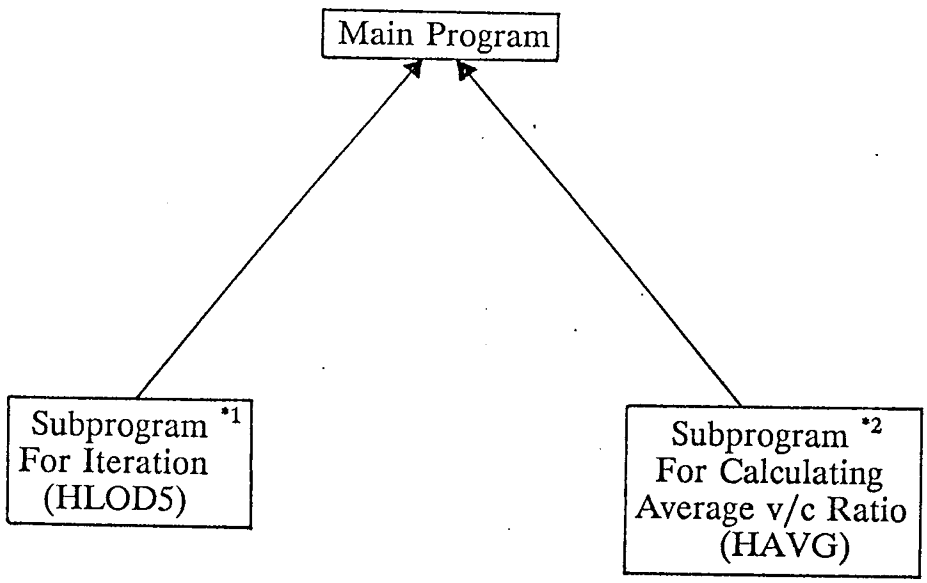



FIGURE 23 General Form of the Impedance Adjustment.




*1 : HLOD5 should be run inside main program.
*2 : HAVG should be run inside both main program and HLOD5; and HAVG is required to calculate at least two sets of competing routes, every iteration corresponding to the number of iteration in HLOD5.

**FIGURE 24 Relationship Between Main Program and Subprograms**

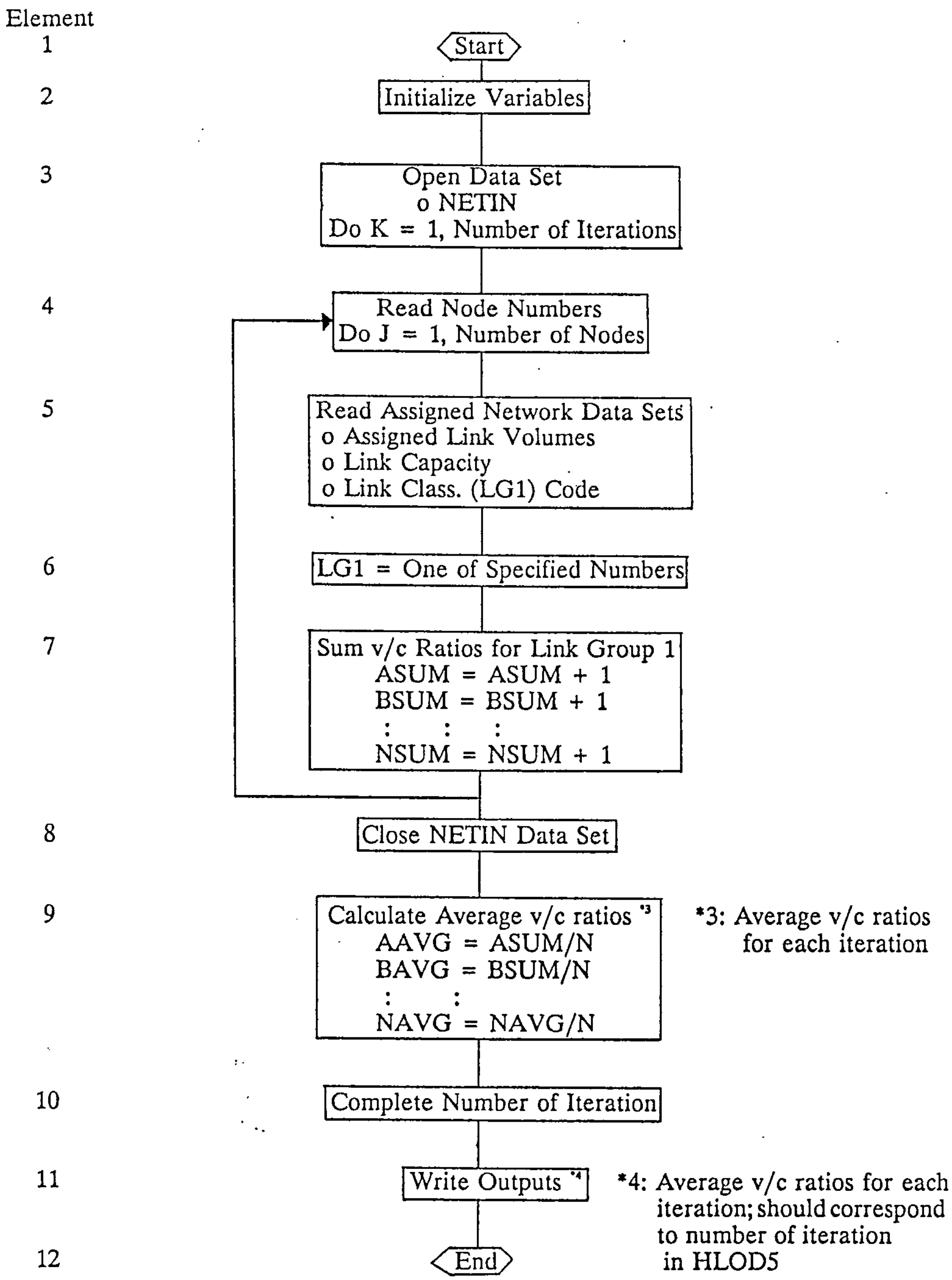



**FIGURE 25 Subroutine for Calculating Average V/C Ratio (HAVG)**

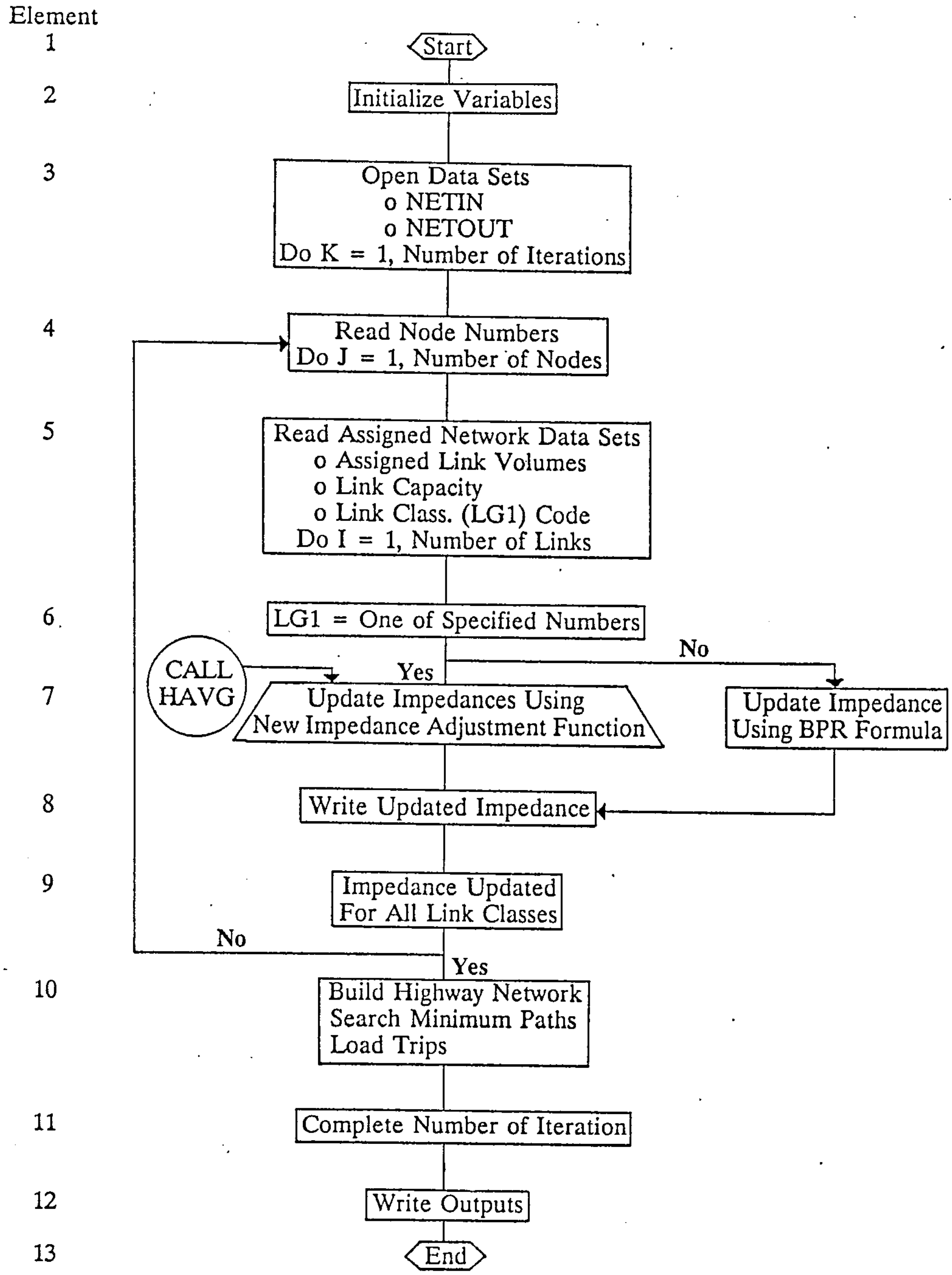



**FIGURE 26 Modified HLOD5 Subprogram**

## Selection and Coding of Test Network

In order to minimize data manipulation, a small urban area was used to test if the microcomputer software worked properly and also to make an initial evaluation of the effectiveness of equalizing link V/C ratios in improving traffic assignments for project-level applicators.

The existing urban transportation network for Tyler, Texas, was used. It consisted of 252 internal zones, 988 modes, and 3,078 one-way links (including the links to external stations but excluding centroid connectors). A project area within the Tyler study area was delineated and used for the project-level analysis (see Figure 27). The network within this project-level area was recoded with smaller zones and with greater network detail (Figure 28). The size of the project area network as originally coded and as recoded in greater detail is:

| | Centroids | Links Excluding Centroid Connectors |
|---|---|---|
| Original network | 15 | 27 |
| Recoded network | 102 | 158 |

Analysis of paths between selected zone pairs in the Tyler network indicated that there were as many as ten different paths with similar total impedances. Therefore, ten iterations of the equalized link V/C ratio restraint assignment were used.

Assignment of existing traffic to the Tyler network, as well as the comparison of counted 24-hour volumes with 24-hour capacities, indicated that few links are at or near capacity. Under these conditions, restraint assignment procedures are not effective. Therefore, the link capacities were multiplied by a factor (0.67) to make the network appear "congested."

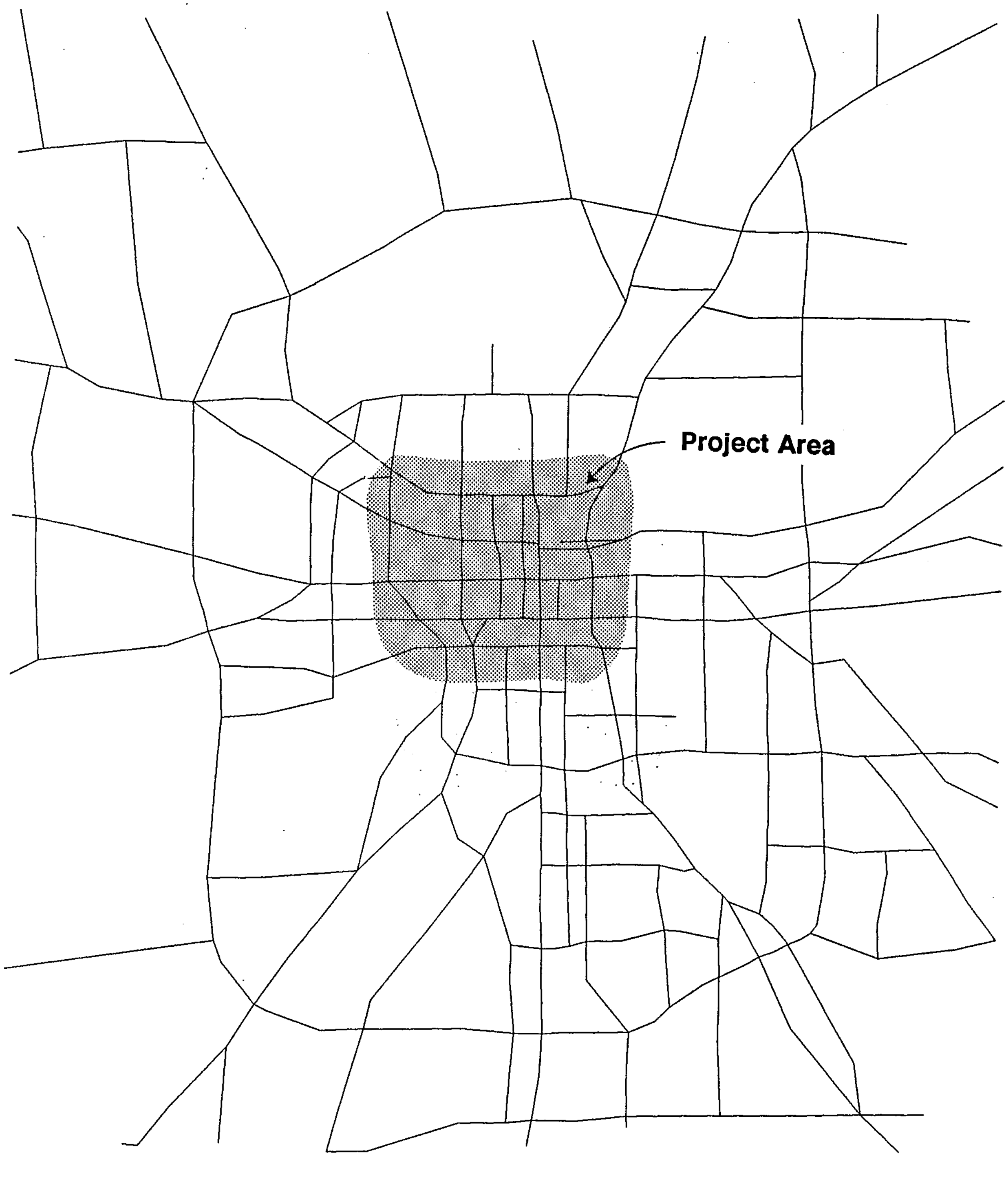



**FIGURE 27 Project Area of the Tyler Network.**

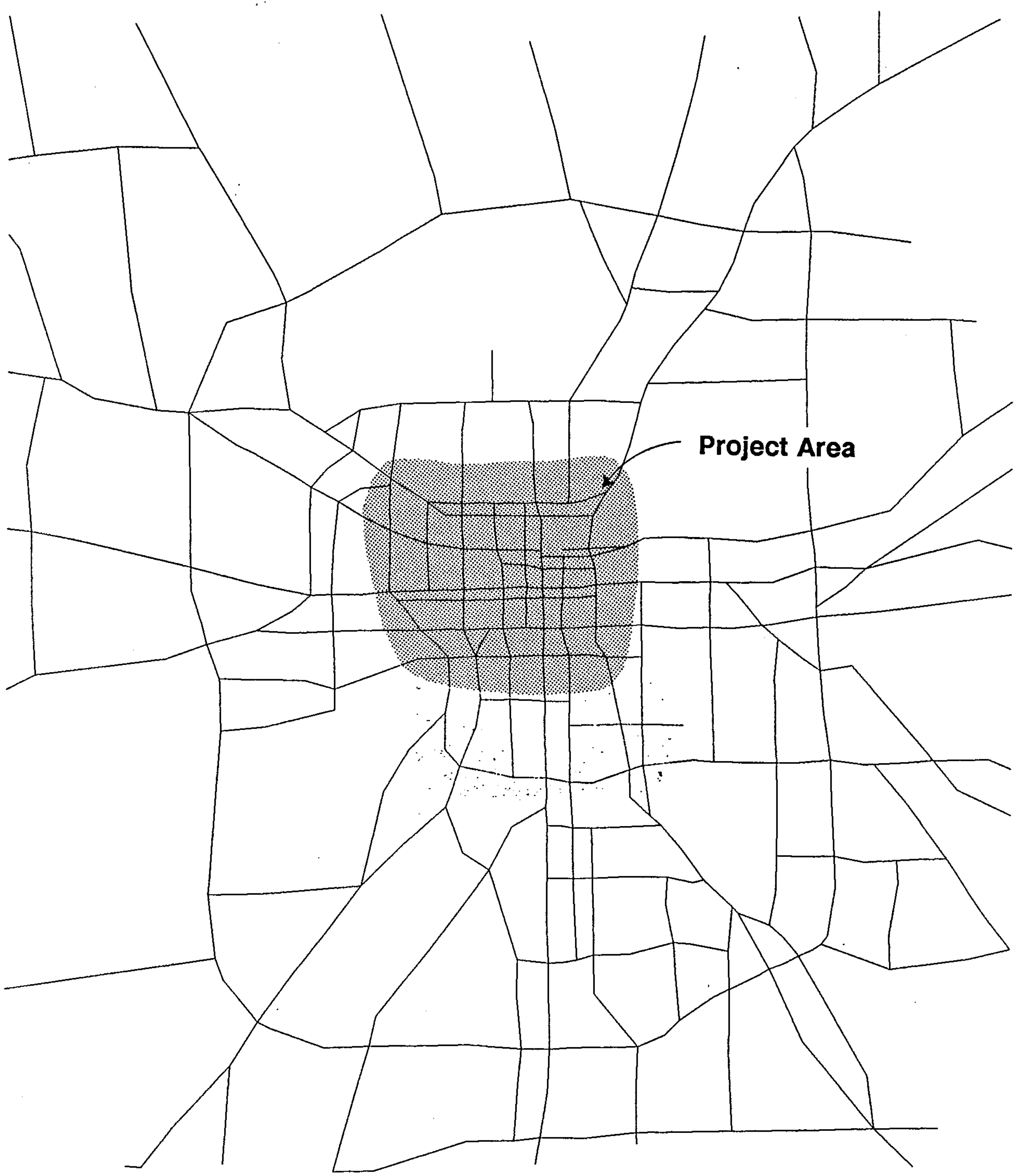



**FIGURE 28 Project Area Recoded in Greater Detail.**

## ANALYSIS

Analysis of the equalized V/C ratio assignment procedure involved the two following principal evaluations:

1. Convergence of the link V/C ratios on competing routes to the average V/C ratio for these routes; and
2. Improvement in turning movements compared to results using the existing restraint assignment procedures.

### Convergence of Link V/C Ratios

The concept of this restraint assignment is that the link V/C ratios on competing routes should converge toward the mean value for each class/category of routes within the project-level area. For the evaluation, 16 individual links, 4 cutlines, and 3 travel routes were selected inside the project area (see Figure 29). The assignment results were produced for from 1 to 10 iterations for both a congested network and a congested and detailed network using the improved assignment technique which equalizes the link V/C ratio.

*Selected Links*

There were three sets of competing routes inside the project area. One set was comprised of four competing east-west major streets, the second was a pair of major north-south streets, and the third was two north-south collector streets. The pattern of link V/C ratios from iteration to iteration was considered to be a major criterion of satisfactory performance.

The data required for evaluation had to be extracted manually. Therefore, two links on each of the routes were selected for determining if the desired closure of the V/C ratios was being obtained. Table 10 contains the link V/C ratios for each of the 10 iterations. The average V/C ratio for each link group is also given for each iteration. Visual inspection shows that the V/C ratios do, in fact, converge toward the average for each link

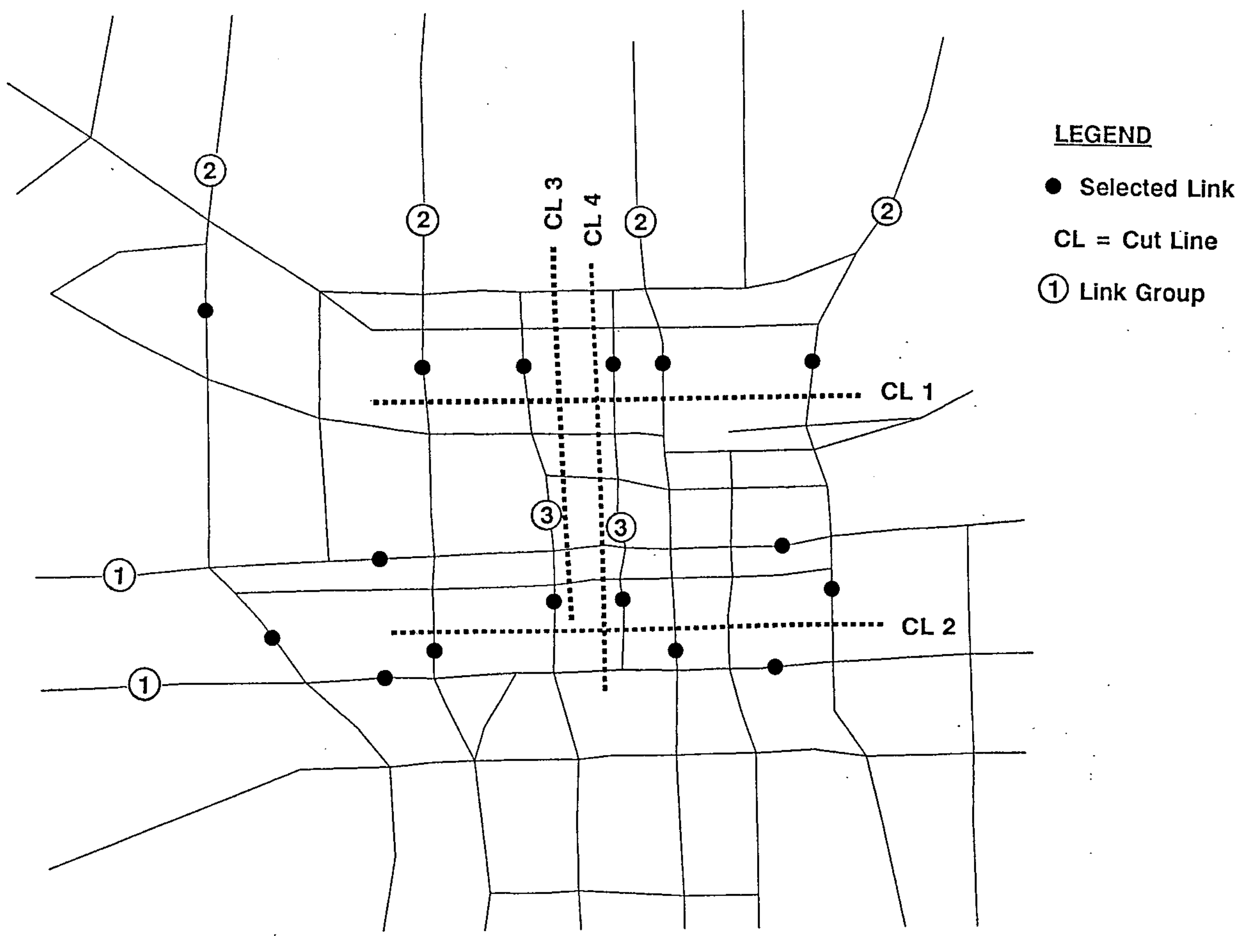



FIGURE 29 Location of Cutlines and Selected Links within Project Area.

group. This trend is especially noticeable for link groups 1 and 3. The standard errors, s, are observed to systematically decrease as well.

Table 11 shows the link V/C ratios for the same selected links in the more detailed. Again, the individual link V/C ratios "closed" on the average V/C ratio of all links in each group. However, the average V/C ratios for each link group are somewhat lower than in Table 10. This results because the more detailed network offers more paths through the network. This in turn results in lower assigned volumes on the selected links. Inspection of Table 11 indicates that the standard error on the tenth iteration is less than on the first. However, the pattern of the diverse is not as "smooth" as for the original network (Table 10).

The F-test was performed to determine if the variance on the tenth iteration was significantly less than on the first iteration. The equalized link V/C ratio method was expected to produce link V/C ratios which converge toward the average V/C ratio for each group; hence, the variance should decrease. Therefore a one-tail test was employed; all tests were made at the 10% significance level. As shown in Table 12, the F-test for differences in variances, $s^2$, indicated that the reduction from the first to the tenth iteration is statistically significant at the 10% significance level for link groups 1 and 2 for the original network. The reduction in the variance from the first to the tenth iteration was not statistically significant (at the 10% significance level) for link group 3. Similar results were achieved with the more detailed network. The reduction in the variance, $s^2$, for link groups 1 and 2 is statistically significant at the 10% significance level. However, the reduction is not statistically significant for link group 3.

The links in Groups 3 are on two north-south collector-type facilities which are entirely within the project area. The very limited continuity of these routes restricts the opportunity for path diversion from iteration to iteration. Therefore, there is limited opportunity for the variation in the group V/C ratios to decrease. Nevertheless, inspection of Tables 10 and 11 shows that the variation in link V/C ratios tends to decrease with successive iterations for this group of links as well as for the Group 1 and 2 links.

TABLE 10 LINK V/C RATIOS BY ITERATIONS FOR THE ORIGINAL NETWORK

| Link Group | Selected Links | Iteration 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 662-663 | 0.26 | 0.37 | 0.46 | 0.46 | 0.56 | 0.59 | 0.70 | 0.69 | 0.79 | 0.76 |
| 1 | 659-670 | 0.57 | 0.74 | 0.94 | 0.92 | 0.94 | 0.81 | 0.74 | 0.68 | 0.63 | 0.73 |
| | 614-616 | 0.48 | 0.47 | 0.50 | 0.53 | 0.67 | 0.72 | 0.83 | 0.79 | 0.78 | 0.75 |
| | 612-628 | 0.79 | 0.72 | 0.94 | 0.80 | 0.77 | 0.68 | 0.65 | 0.62 | 0.75 | 0.75 |
| Average V/C Ratio | | 0.66 | 0.58 | 0.62 | 0.58 | 0.64 | 0.61 | 0.68 | 0.66 | 0.77 | 0.74 |
| Standard Error | | 0.233 | 0.159 | 0.247 | 0.213 | 0.169 | 0.120 | 0.083 | 0.070 | 0.072 | 0.013 |
| | 471-472 | 0.50 | 0.45 | 0.50 | 0.57 | 0.67 | 0.65 | 0.67 | 0.69 | 0.78 | 0.74 |
| | 474-475 | 0.48 | 0.71 | 0.89 | 0.81 | 0.83 | 0.77 | 0.74 | 0.72 | 0.75 | 0.72 |
| | 497-498 | 0.49 | 0.77 | 0.86 | 0.79 | 0.76 | 0.76 | 0.84 | 0.80 | 0.80 | 0.78 |
| | 500-510 | 1.18 | 0.70 | 0.55 | 0.49 | 0.61 | 0.62 | 0.84 | 0.84 | 0.92 | 0.91 |
| 2 | 668-669 | 0.93 | 0.79 | 0.91 | 0.90 | 1.02 | 0.80 | 0.92 | 0.84 | 0.83 | 0.79 |
| | 659-661 | 0.56 | 1.01 | 1.30 | 1.17 | 1.11 | 1.02 | 1.00 | 0.92 | 1.04 | 1.00 |
| | 625-626 | 0.59 | 0.89 | 1.11 | 0.99 | 0.88 | 0.75 | 0.67 | 0.69 | 0.74 | 0.82 |
| | 612-613 | 1.41 | 0.75 | 0.61 | 0.65 | 0.82 | 0.86 | 1.01 | 0.92 | 1.01 | 0.99 |
| Average V/C Ratio | | 0.87 | 0.79 | 0.83 | 0.79 | 0.84 | 0.80 | 0.85 | 0.83 | 0.89 | 0.86 |
| Standard Error | | 0.353 | 0.154 | 0.261 | 0.211 | 0.156 | 0.118 | 0.128 | 0.093 | 0.114 | 0.104 |
| | 478-479 | 0.65 | 0.39 | 0.32 | 0.27 | 0.23 | 0.27 | 0.34 | 0.37 | 0.49 | 0.49 |
| 3 | 482-483 | 0.41 | 0.21 | 0.31 | 0.43 | 0.47 | 0.41 | 0.37 | 0.38 | 0.34 | 0.41 |
| | 620-622 | 0.45 | 0.23 | 0.25 | 0.31 | 0.30 | 0.29 | 0.30 | 0.34 | 0.51 | 0.52 |
| | 502-618 | 0.21 | 0.15 | 0.12 | 0.21 | 0.23 | 0.33 | 0.58 | 0.43 | 0.58 | 0.58 |
| Average V/C Ratio | | 0.44 | 0.32 | 0.29 | 0.30 | 0.34 | 0.35 | 0.40 | 0.38 | 0.46 | 0.45 |
| Standard Error | | 0.157 | 0.116 | 0.089 | 0.081 | 0.103 | 0.059 | 0.108 | 0.032 | 0.117 | 0.079 |

TABLE 11 LINK V/C RATIOS BY ITERATION FOR THE DETAILED PROJECT NETWORK

| Link Group | Selected Links | Iteration 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 662-663 | 0.16 | 0.49 | 0.54 | 0.51 | 0.48 | 0.44 | 0.46 | 0.44 | 0.64 | 0.64 |
| 1 | 659-670 | 0.60 | 0.49 | 0.62 | 0.76 | 0.89 | 0.94 | 0.80 | 0.70 | 0.63 | 0.57 |
| | 614-1026 | 0.70 | 0.66 | 0.54 | 0.45 | 0.47 | 0.44 | 0.55 | 0.51 | 0.59 | 0.58 |
| | 612-628 | 0.88 | 0.45 | 0.34 | 0.31 | 0.38 | 0.38 | 0.51 | 0.50 | 0.71 | 0.72 |
| Average V/C Ratio | | 0.49 | 0.51 | 0.54 | 0.51 | 0.56 | 0.53 | 0.59 | 0.57 | 0.67 | 0.64 |
| Standard Error | | 0.282 | 0.082 | 0.108 | 0.163 | 0.202 | 0.227 | 0.131 | 0.103 | 0.051 | 0.061 |
| | 471-472 | 0.40 | 0.27 | 0.55 | 0.66 | 0.81 | 0.78 | 0.74 | 0.67 | 0.66 | 0.61 |
| | 474-475 | 0.43 | 0.95 | 0.82 | 0.69 | 0.63 | 0.58 | 0.71 | 0.68 | 0.75 | 0.72 |
| | 497-498 | 0.43 | 0.58 | 0.82 | 0.81 | 0.85 | 0.77 | 0.74 | 0.66 | 0.64 | 0.60 |
| 2 | 500-510 | 1.20 | 0.78 | 0.70 | 0.64 | 0.71 | 0.66 | 0.80 | 0.78 | 0.94 | 0.91 |
| | 668-669 | 0.96 | 0.54 | 0.75 | 0.81 | 0.95 | 0.86 | 0.82 | 0.76 | 0.74 | 0.69 |
| | 659-661 | 0.41 | 1.12 | 1.15 | 1.00 | 0.94 | 0.84 | 0.83 | 0.81 | 0.94 | 0.90 |
| | 625-626 | 0.42 | 1.01 | 0.59 | 0.56 | 0.68 | 0.68 | 0.76 | 0.73 | 0.82 | 0.75 |
| | 612-613 | 1.35 | 0.71 | 0.61 | 0.94 | 0.64 | 0.65 | 0.79 | 0.80 | 0.91 | 0.92 |
| Average V/C Ratio | | 0.76 | 0.70 | 0.74 | 0.70 | 0.74 | 0.69 | 0.73 | 0.70 | 0.77 | 0.74 |
| Standard Error | | 0.382 | 0.266 | 0.180 | 0.154 | 0.126 | 0.100 | 0.059 | 0.067 | 0.117 | 0.126 |
| | 478-479 | 0.37 | 0.32 | 0.46 | 0.39 | 0.38 | 0.36 | 0.36 | 0.39 | 0.44 | 0.42 |
| 3 | 482-483 | 0.50 | 0.33 | 0.31 | 0.29 | 0.49 | 0.46 | 0.49 | 0.46 | 0.48 | 0.45 |
| | 620-1034 | 0.44 | 0.27 | 0.22 | 0.20 | 0.34 | 0.48 | 0.57 | 0.56 | 0.56 | 0.63 |
| | 502-1036 | 0.20 | 0.40 | 0.45 | 0.45 | 0.41 | 0.38 | 0.37 | 0.39 | 0.51 | 0.55 |
| Average V/C Ratio | | 0.39 | 0.32 | 0.34 | 0.33 | 0.38 | 0.38 | 0.47 | 0.44 | 0.48 | 0.46 |
| Standard Error | | 0.113 | 0.047 | 0.102 | 0.096 | 0.060 | 0.065 | 0.090 | 0.070 | 0.047 | 0.098 |

TABLE 12 TEST FOR SIGNIFICANCE OF THE REDUCTION IN VARIANCE WITHIN LINK GROUPS

| Network | Link Group | Variance, $s^2$ 1st Iteration | Variance, $s^2$ 10th Iteration | F-Value Calculated | F-Value Critical | Decision (1) |
|---|---|---|---|---|---|---|
| **Original** | 1 | 0.0544 | 0.0107 | 5.08 | 4.11 | Accept $H_a$ |
| | 2 | 0.1249 | 0.0107 | 11.70 | 2.59 | Accept $H_a$ |
| | 3 | 0.1249 | 0.0062 | 4.00 | 4.11 | Reject $H_a$ |
| **Detailed** | 1 | 0.0793 | 0.0037 | 21.40 | 4.11 | Accept $H_a$ |
| | 2 | 0.1659 | 0.0158 | 10.50 | 2.59 | Accept $H_a$ |
| | 3 | 0.0128 | 0.0097 | 1.32 | 4.11 | Reject $H_a$ |

(1) One tail test, 10% significance level

*Cutlines*

Four cutlines were established in the project area (see Figure 29). Cutline 4 is similar to cutline 3 except that it consists of one less link at the south edge of the project area. Inspection of the average V/C ratios for links on each cutline indicates that there is modest change in the ratios (see Table 13). This indicates that for some centroids, the minimum paths shift between routes through the project area and routes not within the area from iteration to iteration. This is not surprising since analysis of the coded Tyler network indicated that there are as many as 10 paths between centroids on either side of the project area which have very similar network travel times.

TABLE 13 AVERAGE CUTLINE V/C RATIOS BY ITERATION FOR THE ORIGINAL CODED NETWORK

| | Cutlines | | | |
|---|---|---|---|---|
| Iteration | 1 | 2 | 3 | 4 |
| 1 | 0.737 | 0.706 | 0.598 | 0.636 |
| 2 | 0.713 | 0.721 | 0.557 | 0.632 |
| 3 | 0.757 | 0.685 | 0.583 | 0.635 |
| 4 | 0.745 | 0.670 | 0.585 | 0.608 |
| 5 | 0.733 | 0.670 | 0.572 | 0.577 |
| 6 | 0.708 | 0.698 | 0.598 | 0.584 |
| 7 | 0.685 | 0.682 | 0.622 | 0.609 |
| 8 | 0.712 | 0.701 | 0.652 | 0.652 |
| 9 | 0.698 | 0.746 | 0.652 | 0.662 |
| 10 | 0.705 | 0.734 | 0.663 | 0.646 |
| Average V/C | 0.719 | 0.710 | 0.607 | 0.624 |

**Comparison of Assigned Turning Movements**

The ideal evaluation of assignment procedures equalizing the V/C ratios on competing routes would be to compare the assigned turning movements with counted volumes. Since counted turning movements were not available, the assignment volumes were compared to the results which were produced by the existing assignment procedure. This procedure was judged to produce the best results when compared to mid-block count data. The incremental procedure was selected as producing better results than the stochastic, iterative,and equilibrium procedures. Four equal incremental loadings were used. Four iterations were also used for the iterative and equilibrium techniques when evaluating the existing restraint assignment techniques.

The following comparisons of the equalized link V/C ratio method and the incremental assignment were made:

1. The Tyler Urban Transportation Study network in the detail as coded was used. The link capacities were reduced as previously indicated to cause the network to react as a "congested" network.
2. That portion of the network within the project area was recoded in greater detail; the detail of the network outside of the project area remained unchanged. The link capacities as previously factored to make the network appear "congested" were used.

Because turning movement counts were not available, the following were used to evaluate the potential improvement of the equalized V/C ratio method (judged to provide better results) over the existing capacity-restraint procedure:

1. Number of zero turning movements.
2. Distribution of the turning movements as a percentage of the approach volume.
3. Paired t-test for difference in mean turn percentages.

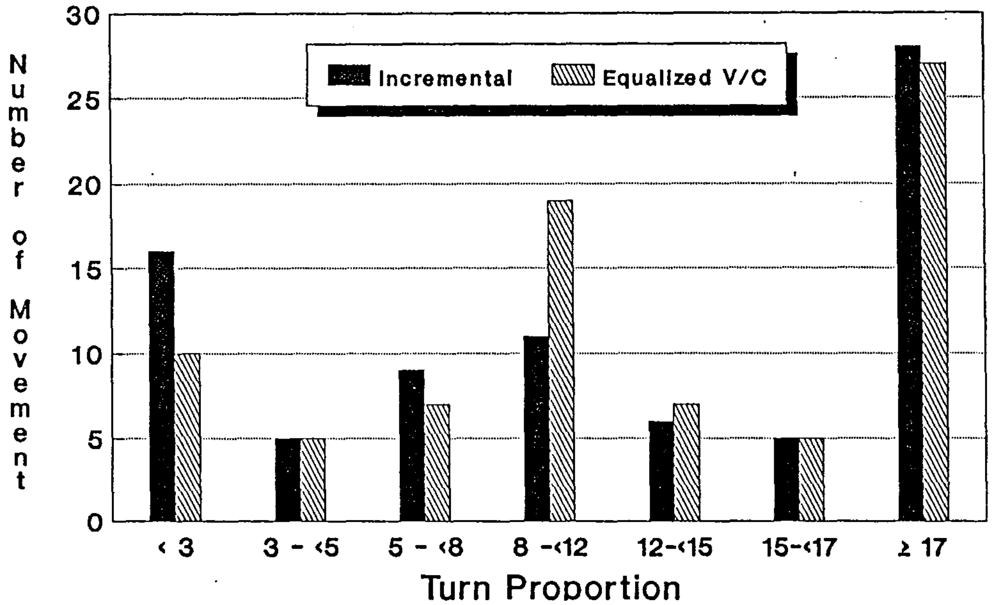
The equalized link V/C ratio method did not produce a significant difference in the number of zero turning movements (see Table 14). There were 5 left-turn and 4 right-turn movements having zero volume within the project area with the incremental assignment. The equalized V/C ratio produced 3 left turns and 4 right turns having zero volume in the network as coded for the Tyler Urban Transportation Study. With the more detailed network recoded for the project area, the equalized link V/C ratio resulted in one left turn and one right turn with zero assigned volume. Detailed analysis of the network indicated that one node can be expected to have a zero left-turn and a zero right-turn volume due to network coding. This may indicate that the method of equalizing link V/C ratios may produce better results than existing restraint assignment techniques when detailed networks are used.

TABLE 14 NUMBER OF ZERO TURNING MOVEMENTS

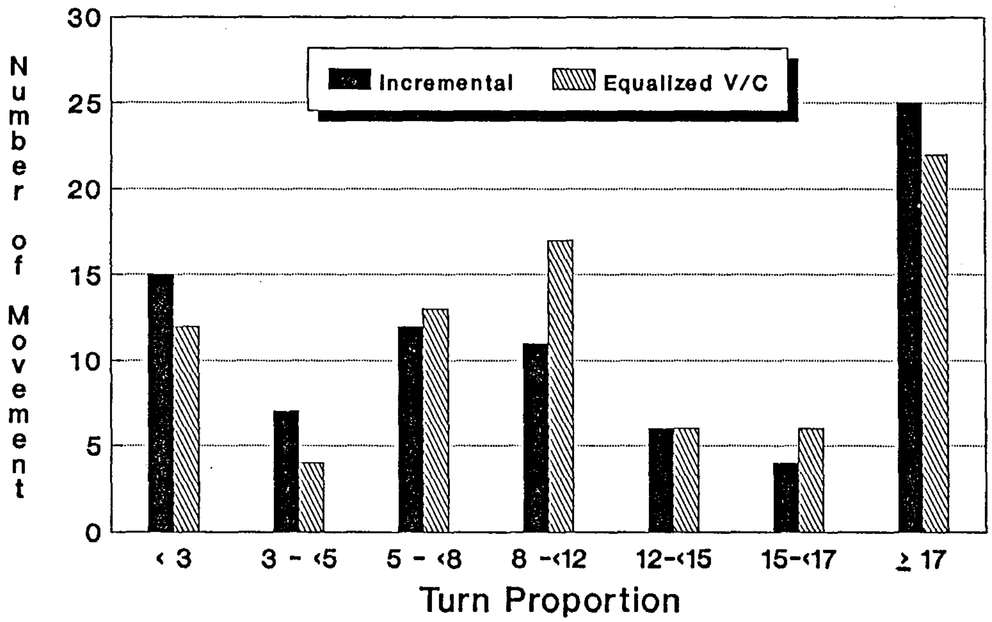
| Network | Incremental | | Equalized V/C Ratio | |
|---|---|---|---|---|
| | Left | Right | Left | Right |
| Network as coded for the Tyler Urban Transportation Study[(1)] | 5 | 4 | 3 | 4 |
| Network recoded to increase detail in the project area[(1)] | 4 | 3 | 1 | 1 |

[(1)] All link capacities were factored by multiplying by 0.67 to make the network appear "congested."

The distribution of turning movements as a percentage of the approach volume is shown in Figures 30, 31, and 32 for left turns, through movements, and right turn, respectively. Approximately 10% left and right turns are generally considered to be typical turn percentages while less than 5% and more than 15% are considered to be exceptional. The equalized link V/C ratio method produced left turn, through movement, and right turn results which appear to be better than the incremental assignment. Namely, the number of movements in the extremes were reduced. The improvement is most noticeable with the left turns (Figure 30) where the number of movements which are less than 3% of the approach volume is reduced by one-third. The number in the 8% to 12% range is nearly doubled. The distribution of right turns was also improved although not as much as the left turns. The number of left and right turns which are more than 17% of the approach volume is high for both assignment methods. This is logical since several of the nodes




As Coded Network




Network Recoded to Add Detail in Project Area

FIGURE 30 Comparison of Left-Turn Percentages from Incremental and Equalized V/C Ratio Assignments.

within the project area represent collector-arterial intersections; such locations have relatively high left and right turn percentages from the collector street approaches.

The through movements, Figure 31, also show a shift toward more logical percentages with the equalized V/C assignment; that is, an increase in the 70% to 85% through movement range.

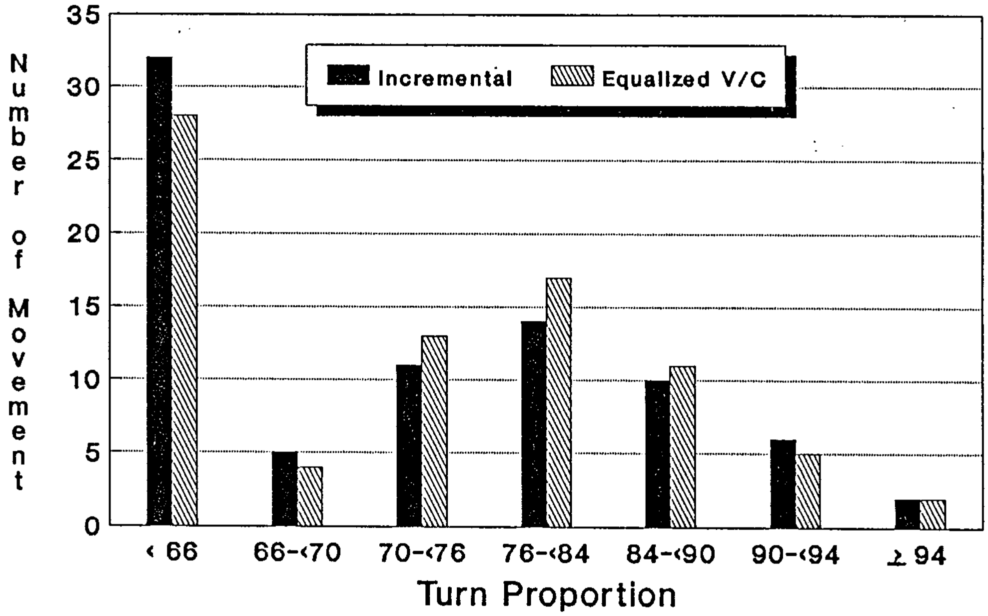
The paired t-test was applied to statistically evaluate the difference between the mean percent left turns, through movements, and right turns. The tests were performed at the 10% significance level. The hypotheses are: null hypothesis, $h_o$: The mean (movement as a percentage of the approach volume) for the equalized link V/C ratio method is the same as the mean for the incremental assignment; and alternate hypothesis, $h_a$: The mean for the equalized link V/C ratio method is different than the mean for the incremental assignment.

The test results are shown in Table 15. The alternate hypothesis is accepted for the difference in the mean percent left turns at the 10% significance level. Therefore, it is concluded that there is a statistically significant difference between the equalized link V/C left-turn assignment results and the incremental assignment. In as much as the equalized V/C method is judged to produce more logical results (as discussed relative to Figure 31) it is concluded that the equalized link V/C assignment on the network in the detail originally coded for the Tyler Urban Transportation Study produced left turns within the project area which are significantly better than the incremental assignment.

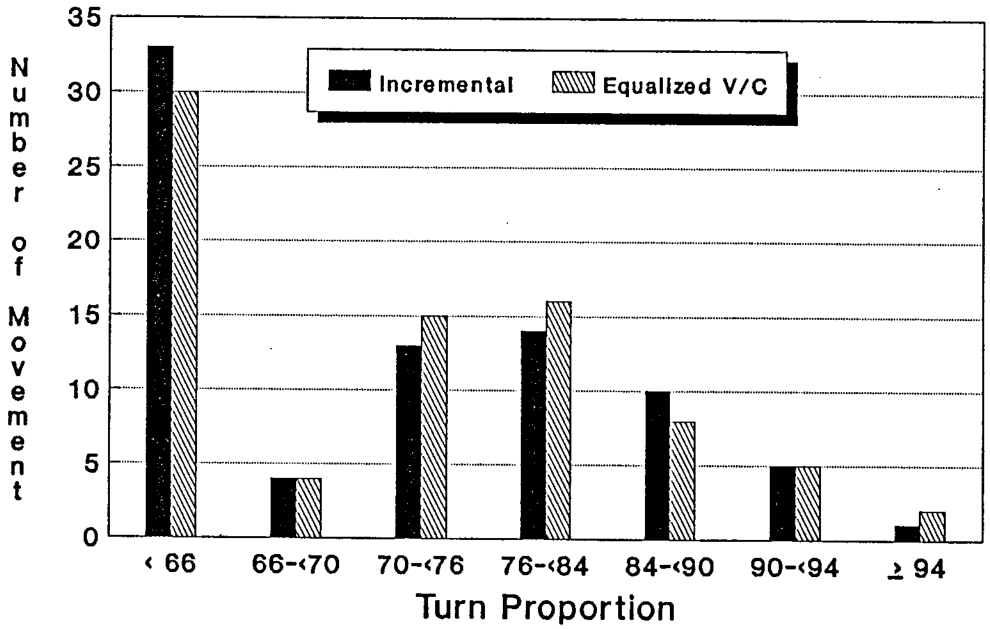
TABLE 15 RESULTS OF PAIRED t-TEST ON MEAN TURNING MOVEMENT PERCENTAGES FOR NETWORK DETAIL AS ORIGINALLY CODED

| | Mean Difference | Standard Deviation | Test Statistic | Decision[1] |
|---|---|---|---|---|
| Left Turn | 1.43 | 10.45 | 1.32 | Accept $H_a$ |
| Through Movement | 1.52 | 14.01 | 0.97 | Reject $H_a$ |
| Right Turn | 0.02 | 13.52 | 0.01 | Reject $H_a$ |

[1] 10% significance level, two-tail test.




As Coded Network




Network Recoded to Add Details in Project Area

FIGURE 31 Comparison of Thru Movement Percentages from Incremental and Equalized V/C Ratio Assignments.

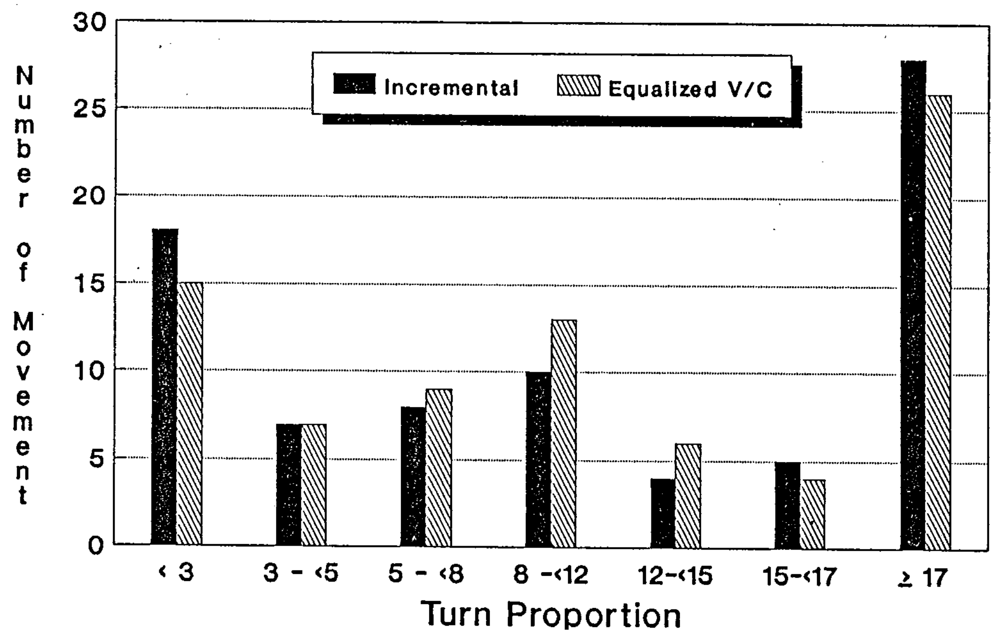
However, the alternate hypothesis for both through movements and right turns is rejected at the 10% significance level. Therefore, it is concluded that the mean turn percentages for these movements could be the same for the equalized link V/C ratio and incremental assignment methods. In other words, there is no statistically significant difference between the mean through and right turn volumes as a percentage of the approach volume. However, while the means are not significantly different for the right turns, the distribution (see Figure 32) is certainly improved. Therefore, it is concluded that the equalized link V/C ratio method did produce improved right turn results.

The improvement in the distribution of the percent through movement is less dramatic than for left turns. Nevertheless, the equalized link V/C ratio results are more logical. Further, since it is concluded that the equalized V/C ratio method produced better left and right turn movements, the through movement must also be improved.

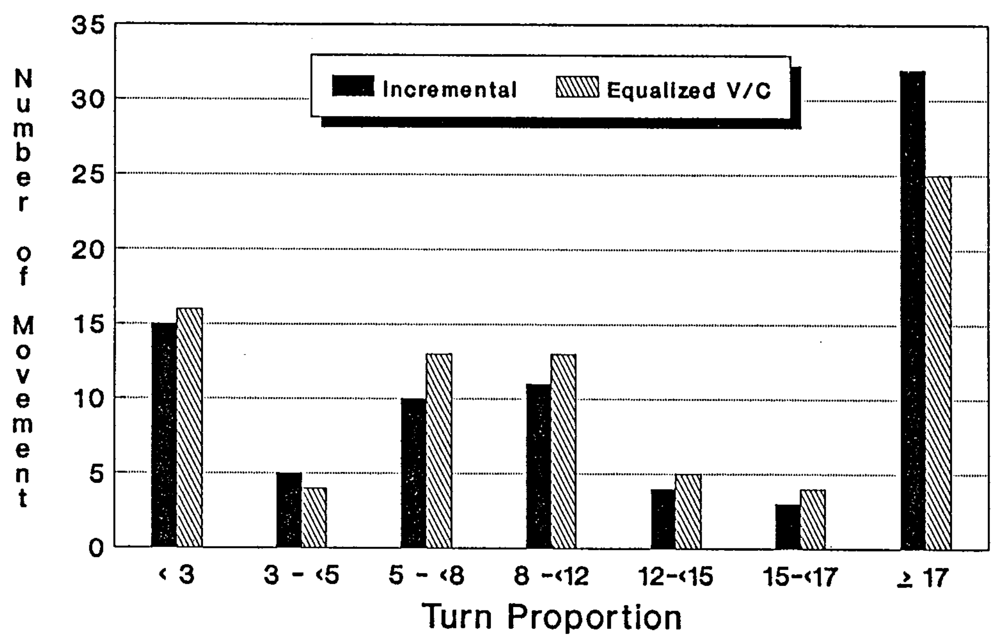
**Conclusions**

Based upon the analysis of the assignment results obtained with the prototype equalized link V/C ratio restraint assignment, the following conclusions and observations are made:

1. The assignment process does perform as intended. Namely, the V/C ratios for links in each link group converge toward the average V/C ratio for the group.
2. The variation in the V/C ratios within each link group is reduced appreciably even though the reduction may not be statistically significant.
3. Cutline V/C ratios did not change appreciably from iteration to iteration. This indicates that while there was some movement of trips between rates through the project area and rates outside the project area, the number of trips was not large. The shifting that did occur appears to be reasonable for the network (i.e., analysis of reasonable alternative paths indicated that as many as 10 different paths may have very similar centroid-to-centroid travel times).
4. The equalized link V/C ratio restraint assignment produced fewer turn movements with zero volume within the project area.




As Coded Network




Network Recoded to Add Detail in Project Area

FIGURE 32 Comparison of Right-Turn Percentages from Incremental and Equalized V/C Ratio Assignments.

5. Evaluation of the distribution of turning movements as a percentage of approach volume indicates that the equalized link V/C ratio restraint assignment produces results which are more reasonable than the existing incremental restraint assignment. By inference it would also produce more logical results than the other existing restraint assignment procedures since the incremental procedure was judged to produce better results when the existing techniques were compared.

# CHAPTER VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The traditional transportation modeling process (trip generation, trip distribution, and traffic assignment) is an excellent tool for evaluation of land-use/transportation alternatives. However, it is generally recognized that such a system level must be refined for project-level applications. NCHRP Report 225 is the most exhaustive documentation of procedures used to refine system-level traffic forecasts for use at the corridor or facility level. Such procedures involve considerable judgment and must be performed by an experienced analyst. Moreover, they are time-consuming and expensive.

A restraint assignment procedure which considers groups of links is hypothesized to provide assignment results that are more applicable to project-level applications than assignments obtained by existing techniques. The simplest approach is to equalize the link V/C ratios on competing routes. This research project investigated the potential of such a procedure. The research also included the investigation of manual corridor analysis procedures and microcomputer applications which would facilitate the conduct of such corridor studies.

There is a critical need to obtain traffic counts at intersections in order to provide a data base for evaluating corridor analysis procedures and project-level traffic assignment techniques.

## CONCLUSIONS

The following is a summary of the conclusions drawn from this research project:

1. Intersection movements, as a percentage of approach volume, may be calculated using a theoretical procedure based upon the relative conflicting volumes. Good correlation between the theoretical and counted percent turns was obtained for high volume approaches. The correlation was very poor where all four approaches were low volume. Also, the theoretical values did not compare favorably with the counted data for the low-volume approaches where the other two opposing approaches were moderate to high volume.

2. The prototype assignment procedure equalizing link V/C ratios on competing routes functions as intended. That is, the V/C ratio of links of the same classification do converge toward the average V/C ratio for the link class as the number of iterations increases.
3. The prototype restraint assignment procedure produced better project-level results than the existing incremental capacity-restraint assignment procedure. Since the incremental procedure was judged to produce better results than the stochastic, iterative, and equilibrium capacity-restraint assignment methods, it is implied that the equalized link V/C ratio method would also produce better project-level assignments than the other existing methods on the Tyler network.
4. There is no difference in the results of the Texas Package and the TRANPLAN results for subarea analysis.
5. There is a significant difference in the results of the manual calculations procedure followed by the Corridor Analysis Group and the TRANPLAN (and Texas Package) results.
6. For the US-290 Case Study the results using capacity-restraint were no better than using all-or-nothing assignment because there is no parallel facility in the Austin network.
7. The proposed new alternative procedure for performing corridor analysis will help produce high quality, consistent, and timely data for prioritization, cost, and design of a project. However, the procedure must be applied with considerable judgment and a knowledgeable analyst.
8. Application of part of the proposed alternative procedure and the computer subarea assignment in the SH-161 Case Study indicated that they produced different results. Since the comparison was for a future year, no traffic counts are available, and there is no certain way to conclude which of the two procedures is better. However, the turning movements, particularly the number of turns with zero volume, are improved with the proposed alternative procedure.

## RECOMMENDATIONS

Recommendations based upon Study No. 1112 are grouped according to those needing further research and those involving implementation:

### Further Research

Recommendations for further research and development are as follows:

1. Conduct turning movement traffic counts at several intersections within an urban corridor in order to perform the following analyses and evaluations.
   (a) Comparison of intersection movements with ground counts obtained using the SDHPT Corridor Analysis Group procedure; also comparison of intersection movements with ground counts using the alternative corridor analysis procedure identified in Chapter 3. Comparison of the difference of the two results.
   (b) Analysis of the ability of the existing capacity-restraint traffic assignment procedures to reproduce ground counts.
   (c) Analysis of the ability of the equalized link V/C ratio restraint assignment procedure to reproduce ground counts.
   (d) Further evaluation of the theoretical procedure for the calculation of turning movements as a percentage of approach volume.
2. Apply the equalized link V/C ratio restraint assignment procedure to a large urban network such as Dallas-Ft. Worth.
3. Further evaluate and refine the impedance adjustment function used in the equalized link V/C ratio and restraint assignment procedure.
4. Determine the optimum number of iterations that should be used when applying the equalized link V/C ratio restraint assignment procedure.
5. Evaluate the equalized link V/C ratio method of restraint assignment to determine the following two options:
   (a) Use of all iterations to obtain the assigned link volumes; or
   (b) Use of last several iterations to obtain the final assigned link volumes.

The number of iterations is determined based on the achievement of stability in the link V/C ratios (for example, the last 4 iterations out of a total of 10 or 12 iterations).

6. Further evaluate the effect of network detail on the assignment results obtained using the equalized link V/C ratio restraint assignment procedure.
7. Develop and test a prototype restraint assignment computer program which applies the traffic restraint at each node in the network (each node represents an intersection).
8. Develop microcomputer software to more fully automate the proposed alternative corridor analysis procedure.
9. Evaluate more thoroughly the proposed alternative corridor analysis procedure.

**Implementation**

Recommendations concerning the implementation of the findings of Study No. 1112 are as follows:

1. Incorporate an equalized link V/C ratio restraint assignment procedure into the TRANPLAN package and Texas Travel Demand Package, including user documentation.
2. Download data from the mainframe computer to a microcomputer for performing subarea analysis. The TRANPLAN package should be used for the subarea modeling.

## BIBLIOGRAPHY


1. Texas Airport System Study, Texas Transportation Institute.
2. Traffic Engineering Short Course Notes, Texas Engineering Extension Service.
3. V. G. Stover and F. J. Koepke. *Transportation and Land Development.* Institute of Transportation Engineers, Prentice Hall, Inc., 1988.
4. V. G. Stover. Accessibility and Access Considerations in the Planning and Design of Urban Activity Centers. Presented at the Transportation Research Board Workshop on Transportation Requirements for Urban Activity Centers, Phoenix, AZ, September 27-28, 1984.
5. Smith, Wilbur, and Associates. *Maryland National Capitol Beltway Impact Study,* 1965.
6. Robert M. Winick. Balancing Future Development and Transportation in a High Growth Area. In *Compendium of Technical Papers,* Institute of Transportation Engineers, 1985.
7. N. J. Pedersen and D. R. Samdahl. Highway Traffic Data for Urbanized Project Planning and Design. *NCHRP Report 255,* Dec. 1982.
8. C. Richard Keller and Joe Mehra. Site Impact Traffic Evaluation (S.I.T.E.). Report FHWA/PL/85/004. Kellerco for the Federal Highway Administration, January 1985.
9. R. W. Eash, B. N. Janson, and D. E. Boyce. Equilibrium Traffic Assignment: Advantages and Implications for Practice. In *Transportation Research Record 944,* TRB, National Research Council, Washington, D.C., 1983, pp. 1-8.
10. R. L. Creighton and J. R. Hamburgh. *Mirco Assignment, Final Report, Volume I - Procedure and Theoretical Background, and Volume II - Program Documentation.* Creighton, Hamburgh Planning Consultants, Bethesda, Maryland, October 1969.
11. V. G. Stover, D. L. Woods, and T. J. Brudeseth. Unpublished research on the development and testing of capacity restraint equations. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1968.

12. J. D. Benson and W. D. Cunagin. *Development and Implementation of a New Impedance Function for Capacity Restraint Traffic Assignment.* Unpublished Report. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1980.

13. V. G. Stover and D. L. Woods. *The Effect of Zone Size on Traffic.* Research Report 60-8. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1967.

14. V. G. Stover and G. D. Long. *The Effect of Network Detail on Traffic Assignment Results.* Research Report 60-11. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1967.

15. R. H. Pratt. *A Method for Distributing Traffic Volumes Among Competing Highway Facilities.* Unpublished Working Report. R. H. Pratt Associates, Kensington, MD, 1976.

16. V. G. Stover, J. D. Benson and J. Buechler J. *A Sensitivity Evaluation of Traffic Assignment.* Research Report 17-2. Texas Transportation Institute, The Texas A&M University System, College Station, TX, 1985.

17. D. M. Chang. *A Sensitivity Analysis of Traffic Assignment.* Ph. D. Dissertation. Texas A&M University, College Station, TX, August 1988.

18. R. L. Creighton and J. R. Hamburgh. "Sensitivity" in Data Requirements for Metropolitan Transportation. *NCHRP 120,* 1971.

19. S. A. Abu-Eisheh and F. L. Mannering. Traffic Forecasting for Small- to Medium-sized Urban Areas. In *ITE Journal,* Oct. 1986, pp. 37-42.

20. R. F. Fleet, R. A. Osborne, and K. G. Hooper. Increasing the Relevance of Planning for Project Development and Engineering Design. In *ITE Journal,* Washington, D.C., May 1989, pp 29-32.

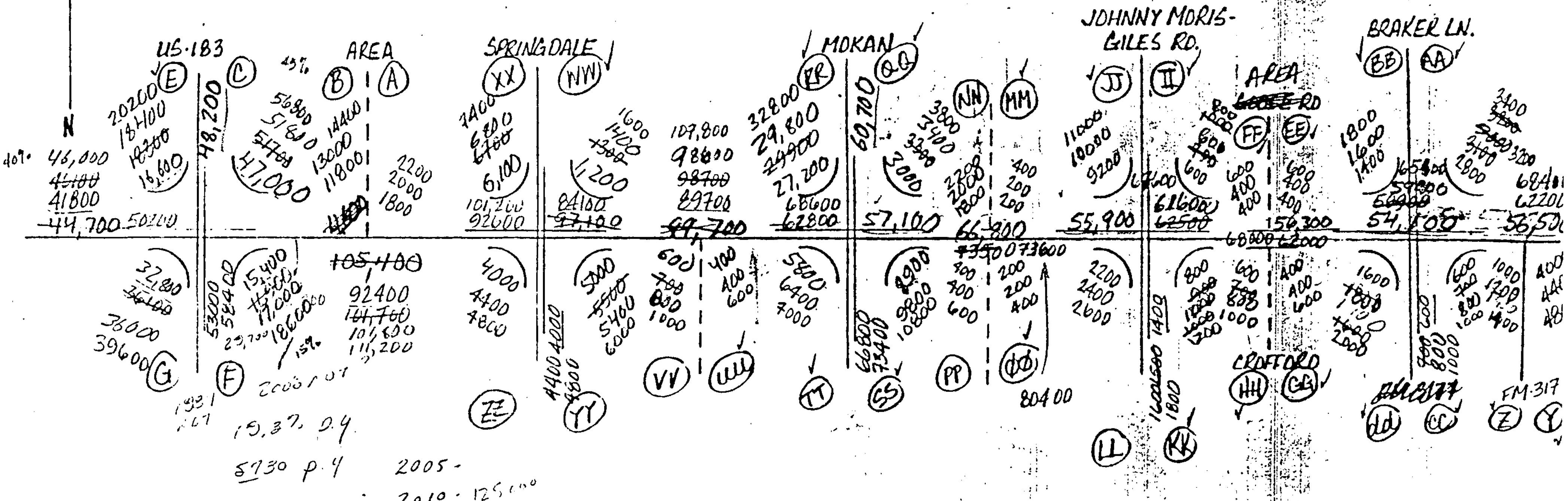
21. D. B. Roden. The Development of a Regional Information Systems and Subarea Analysis Process. In *ITE Journal*, Washington, D.C., Dec. 1988, pp 27-31.

22. D. M. Chang and G. B. Dresser. *Subarea Analysis Using TRANPLAN/NEDS.* Research Report FHWA/TX-87/1110-4F. Texas Transportation Institute, The Texas A&M University System, College Station, TX, Nov. 1988.

## APPENDIX A

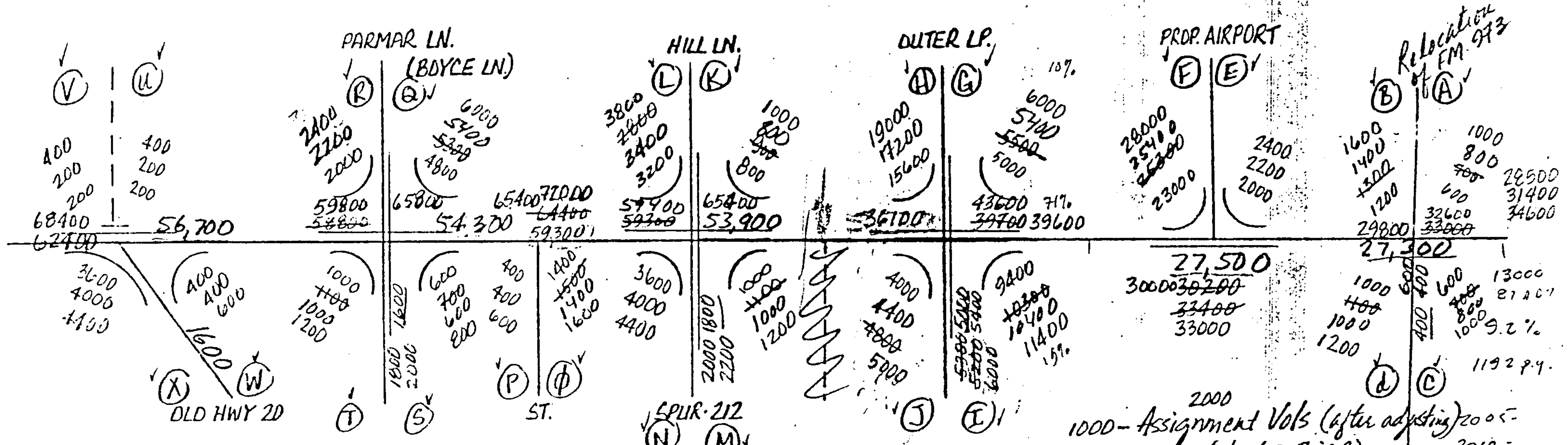
## US-290 Study Worksheet Used in Corridor Analysis Group and Nondirectional Volumes on Schematic Straightline Network.

# DIST. SCHEMATIC STRAIGHT LINE




116

Will use 2.0% GROWTH RATE OVER YR. 2000

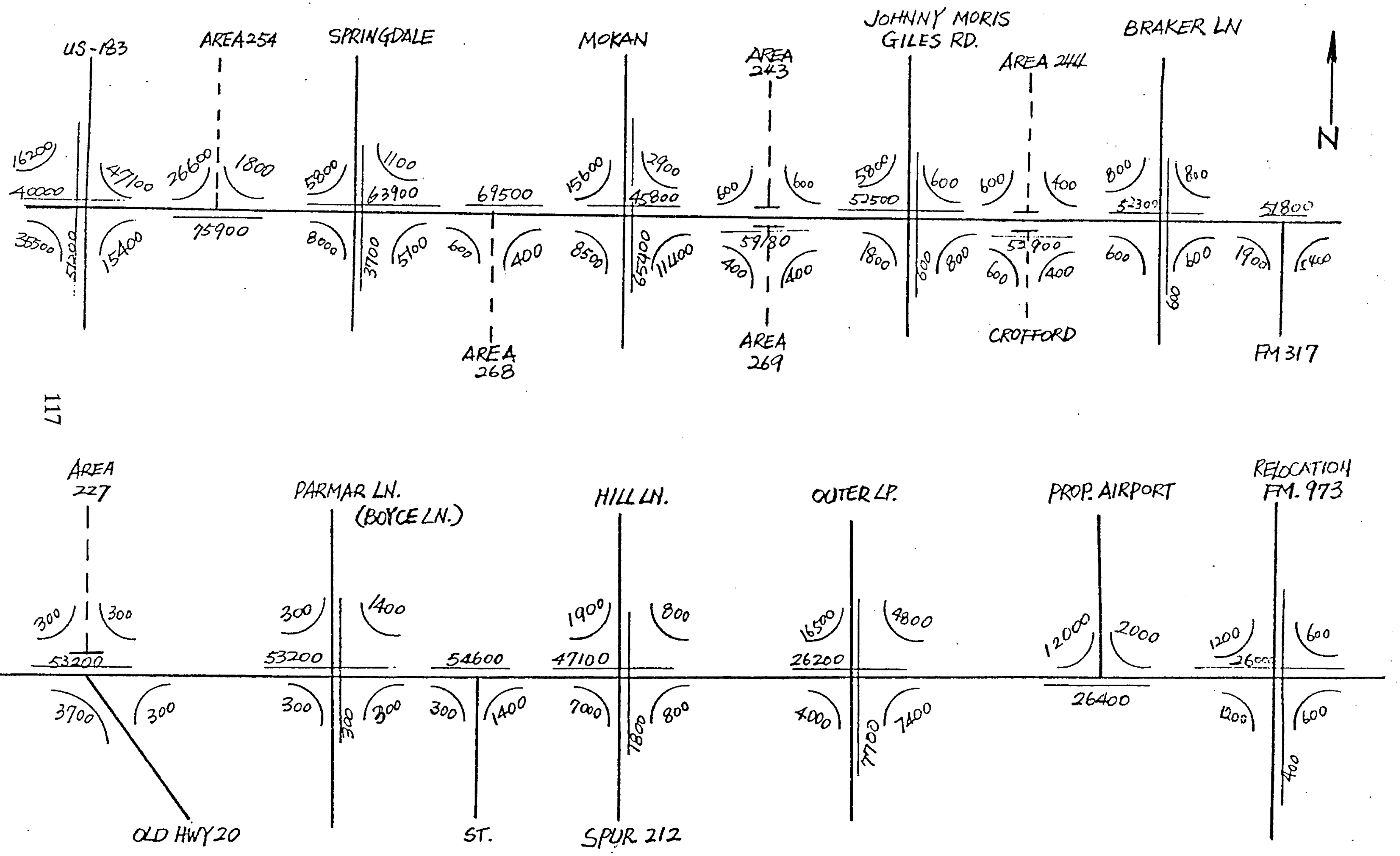



1000 – Assignment Vols (after adjusting) 2000

1000 – 2005 Vols (2.% GR) 2005

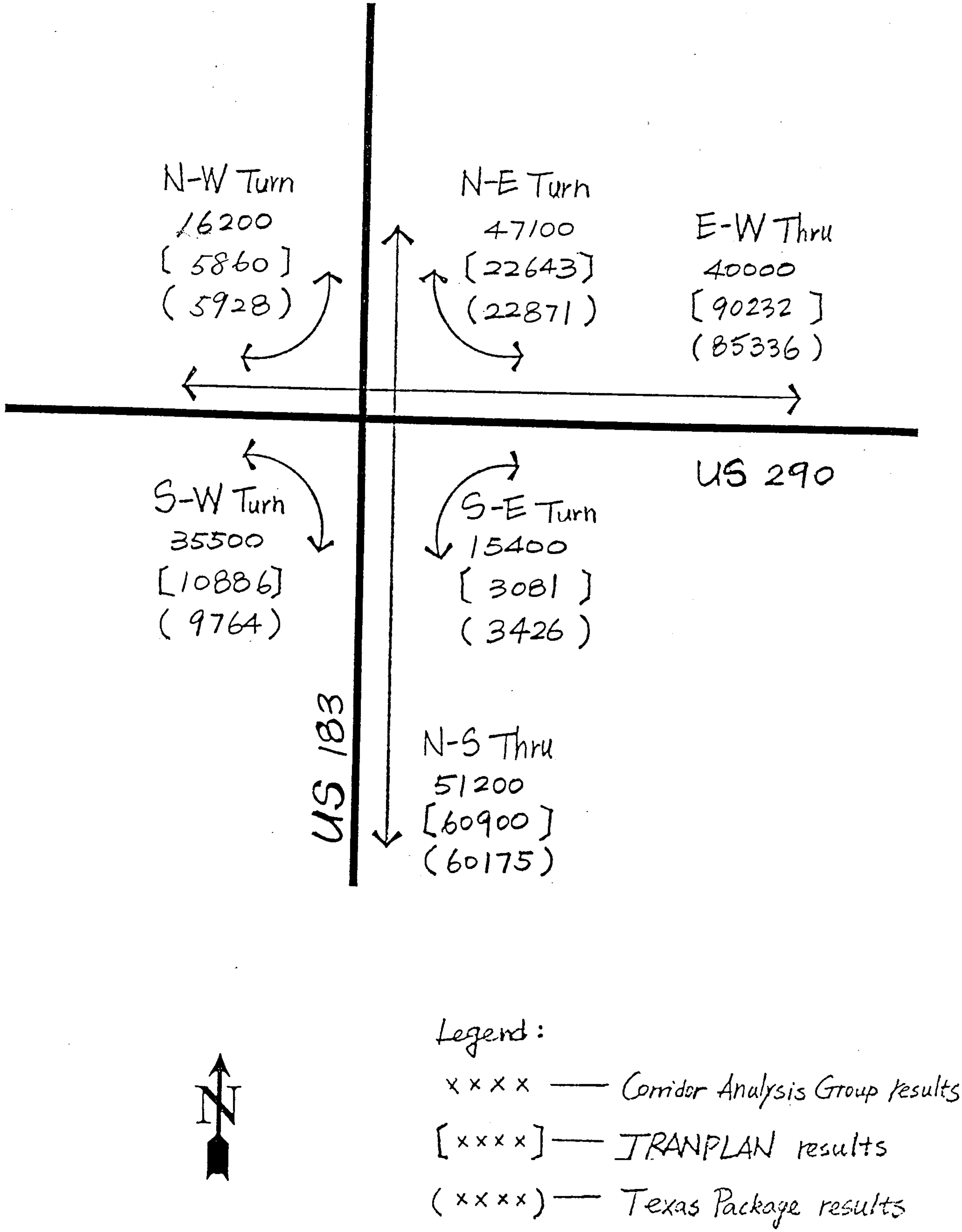
1000 – 2010 Vols (2.% GR) 2010

DIST. SCHEMATIC STRAIGHT LINE

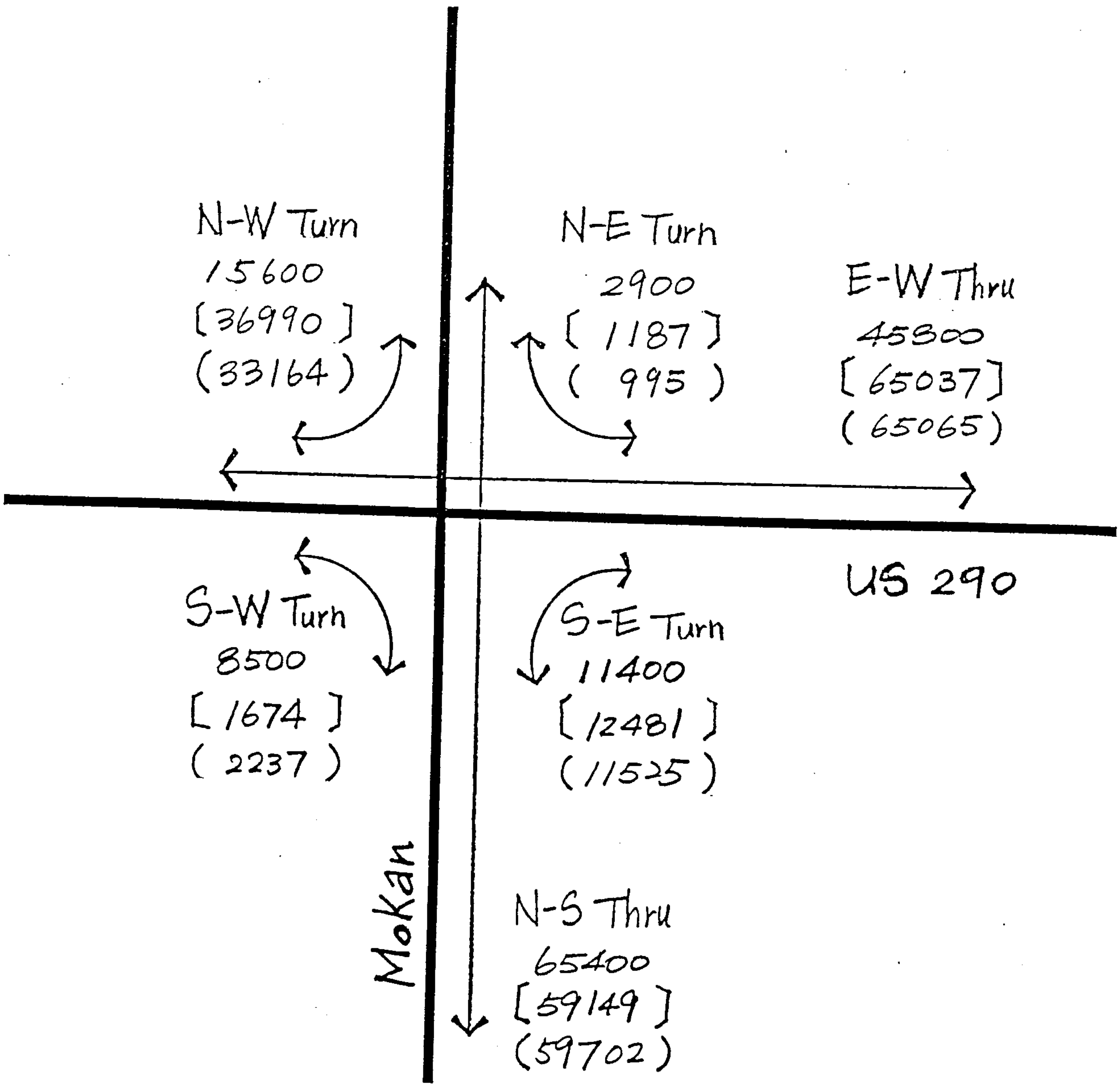


**APPENDIX B**

**Intersection Volumes Along US-290.**




INTERSECTION LOCATION: US 290 - US 183





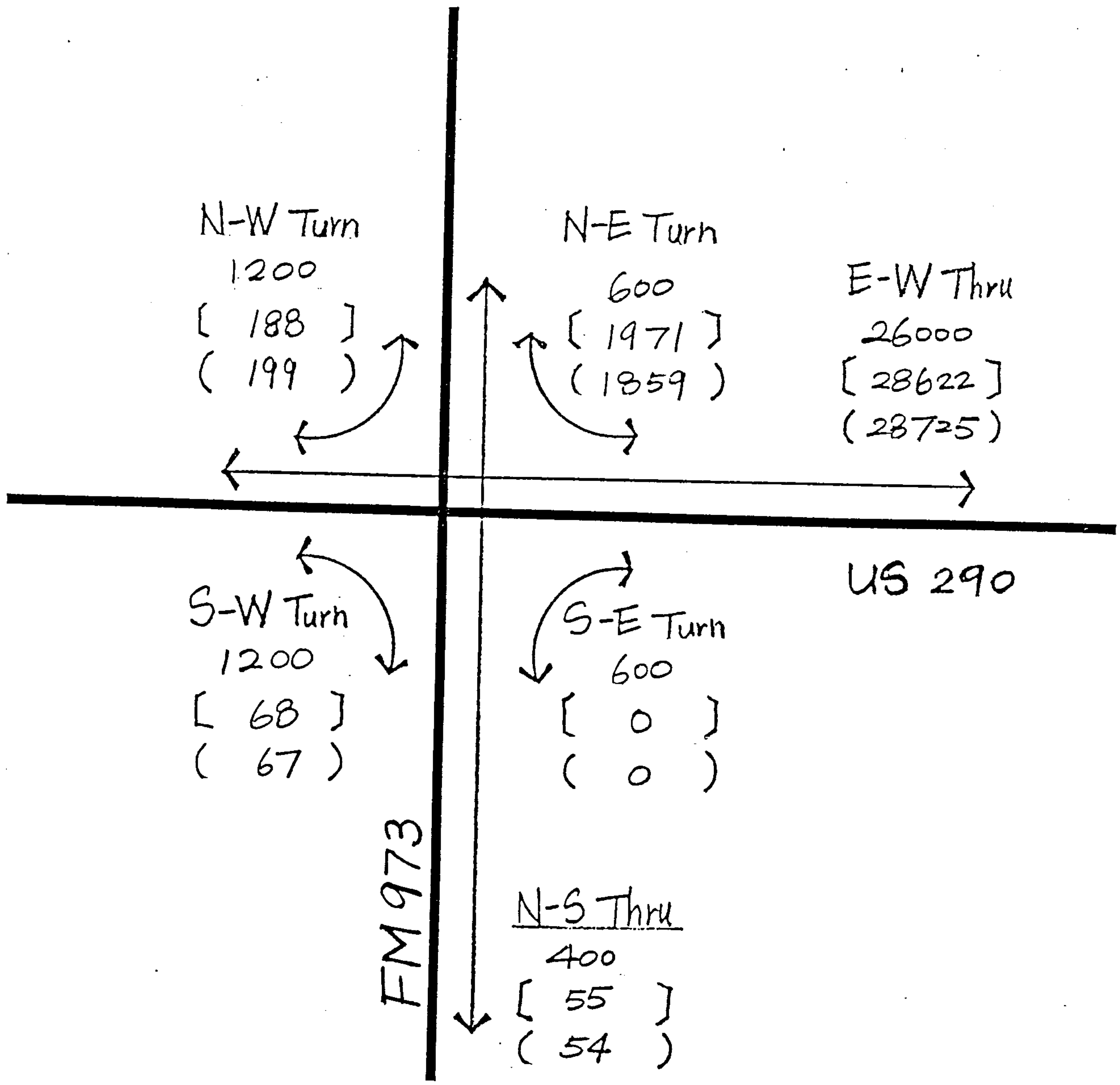
Legend:

xxxx — Corridor Analysis Group results

[xxxx] — TRANPLAN results

(xxxx) — Texas Package results

INTERSECTION LOCATION: US 290 - Mokan




Legend:

xxxx — Corridor Analysis Group results

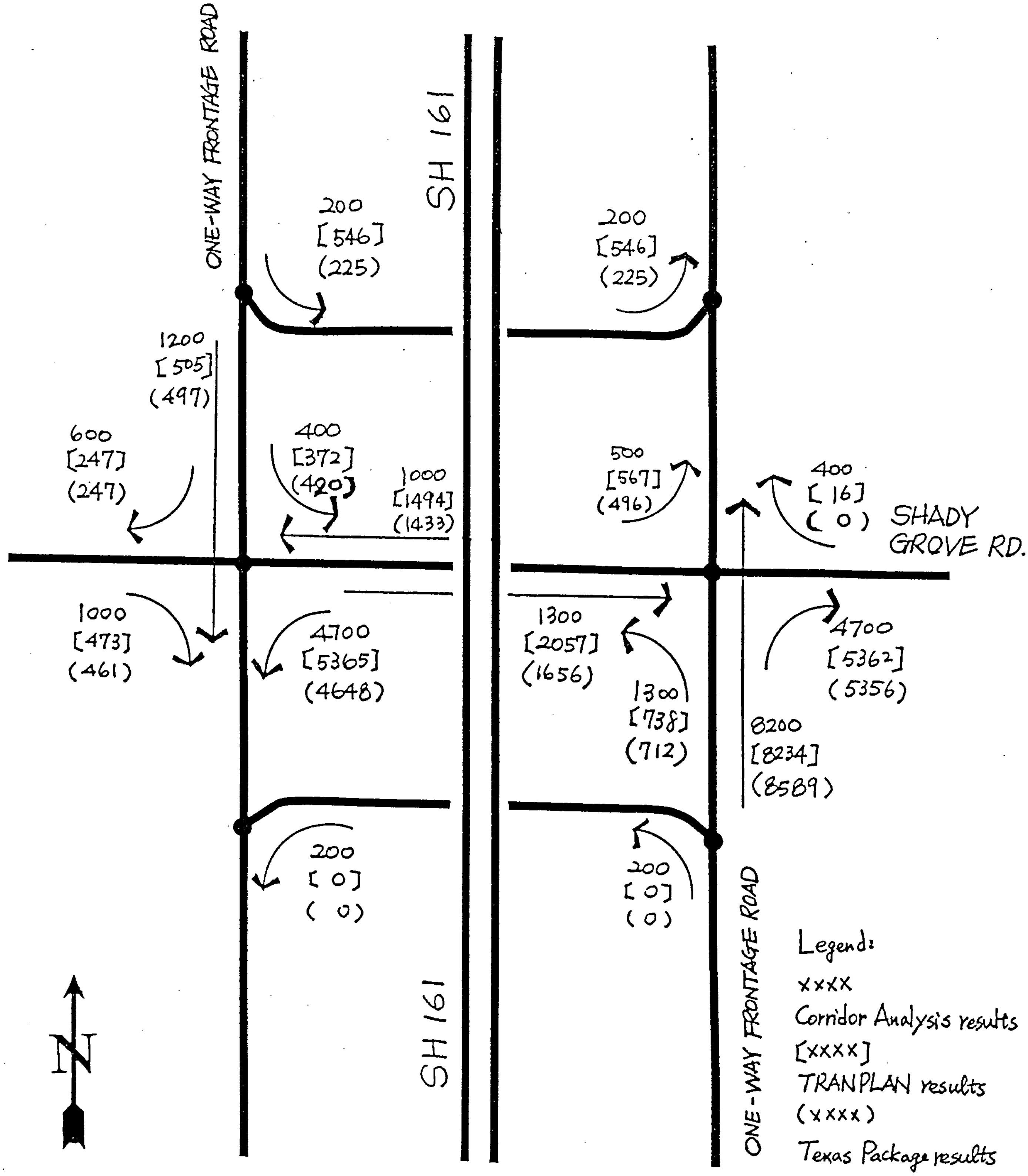
[xxxx] — TRANPLAN results

(xxxx) — Texas Package results


INTERSECTION LOCATION: US 290 - FM 973

## APPENDIX C

## An Example of Turning Movements at SH-161.




INTERSECTION LOCATION: SH161 – SHADY GROVE RD.

## APPENDIX D

## Turning Movement Iterative Procedure Using Lotus.

FUTURE DIRECTIONAL TURN VOLUMES FROM FUTURE DIRECTIONAL LINK VOLUMES
NCHRP 255, PAGE 105 Written by: FHWA (C. Fleet)
*** INPUT DATA *** Modified by: COMSIS Corp. (M. Roskin) 4/9/86

| APPROACH | TURN MOVEMENT | BY COUNT | APPROACH | FY TOTAL |
|---|---|---|---|---|
| NORTH | LEFT | 3,500 | NORTHBOUND | |
| BOUND | THRU | 700 | IN ... | 2,232 |
| | RIGHT | 800 | OUT ... | 2,425 |
| SOUTH | LEFT | 500 | SOUTHBOUND | |
| BOUND | THRU | 1,000 | IN ... | 2,587 |
| | RIGHT | 1,800 | OUT ... | 2,081 |
| EAST | LEFT | 700 | EASTBOUND | |
| BOUND | THRU | 7,900 | IN ... | 10,537 |
| | RIGHT | 3,400 | OUT ... | 9,124 |
| WEST | LEFT | 600 | WESTBOUND | |
| BOUND | THRU | 8,400 | IN ... | 5,883 |
| | RIGHT | 500 | OUT ... | 7,609 |

*** INPUT DATA ***

| | | OUTBOUND LINK | | | | | | BASE INFLOW | FUTURE INFLOW |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | | |
| | 1 | NA | 700 | 7900 | 3400 | | | 12000 | 10537 |
| INBOUND | 2 | 1800 | NA | 500 | 1000 | | | 3300 | 2587 |
| | 3 | 8400 | 500 | NA | 600 | | | 9500 | 5883 |
| LINK | 4 | 3500 | 700 | 800 | NA | | | 5000 | 2232 |
| | 5 | | | | | NA | | 0 | |
| | 6 | | | | | | NA | 0 | |
| BASE . . . | | 13700 | 1900 | 9200 | 5000 | 0 | 0 | 29800 | |
| FUTURE . . | | 9124 | 2081 | 7609 | 2425 | | | | 21239 |

***FIRST ROW ITERATION FOLLOWS

| | | OUTBOUND LINK | | | | | | FUTURE INFLOW |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | |
| | 1 | 0 | 614.65 | 6936.8 | 2985.4 | 0 | 0 | 10537 |
| INBOUND | 2 | 1411.0 | 0 | 391.96 | 783.93 | 0 | 0 | 2587 |
| | 3 | 5201.8 | 309.63 | 0 | 371.55 | 0 | 0 | 5883 |
| LINK | 4 | 1562.4 | 312.48 | 357.12 | 0 | 0 | 0 | 2232 |
| | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADJ.FUT. | | 08175.3 | 1236.7 | 7685.9 | 4140.9 | 0 | 0 | 21239 |
| FUTURE OUT | | 9124 | 2081 | 7609 | 2425 | 0 | 0 | 21239 |
| DIFFERENCE | | -10.39 | -40.56 | 1.0112 | 70.762 | 0 | 0 | |

***FIRST COLUMN ITERATION FOLLOWS *******

| | | OUTBOUND LINK | | | | | | ADJ.FUT. INFLOW | FUT. FLOW | INDIFF. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | | | |
| | 1 | 0 | 1034.2 | 6867.4 | 1748.3 | 0 | 0 | 9649.9 | 10537 | -8.41 |
| INBOUND | 2 | 1574.8 | 0 | 388.04 | 459.08 | 0 | 0 | 2421.9 | 2587 | -6.37 |
| | 3 | 5805.4 | 520.98 | 0 | 217.58 | 0 | 0 | 6544.0 | 5883 | 11.23 |
| LINK | 4 | 1743.7 | 525.78 | 353.54 | 0 | 0 | 0 | 2623.0 | 2232 | 17.51 |
| | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FUTURE OUT | | 9124 | 2081 | 7609 | 2425 | 0 | 0 | 21239 | 21239 | |

***SECOND ROW ITERATION FOLLOWS *******

| | | OUTBOUND LINK | | | | | | FUTURE INFLOW |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | |
| | 1 | 0 | 1129.2 | 7498.6 | 1909.0 | 0 | 0 | 10537 |
| INBOUND | 2 | 1682.1 | 0 | 414.48 | 490.36 | 0 | 0 | 2587 |
| | 3 | 5219.0 | 468.36 | 0 | 195.60 | 0 | 0 | 5883 |
| LINK | 4 | 1483.7 | 447.39 | 300.83 | 0 | 0 | 0 | 2232 |
| | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ADJ.FUT.OU | | 8384.9 | 2045.0 | 8213.9 | 2595.0 | 0 | 0 | 21239 |
| FUTURE OUT | | 9124 | 2081 | 7609 | 2425 | 0 | 0 | 21239 |
| DIFFERENCE | | -20.42 | -1.727 | 7.9510 | 7.0107 | 0 | 0 | |

***SECOND COLUMN ITERATION FOLLOWS *******

*** RESULTS ***

| | | OUTBOUND LINK | | | | | | ADJ FUTURE INFLOW | START FUTURE INFLOW | (%) DIFF |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | | | |
| | 1 | NA | 1,149 | 6,946 | 1,784 | 0 | 0 | 9,879 | 10,537 | -6.2 |
| INBOUND | 2 | 1,830 | NA | 384 | 458 | 0 | 0 | 2,673 | 2,587 | 3.3 |
| | 3 | 5,679 | 477 | NA | 183 | 0 | 0 | 6,338 | 5,883 | 7.7 |
| LINK | 4 | 1,615 | 455 | 279 | NA | 0 | 0 | 2,348 | 2,232 | 5.2 |
| | 5 | 0 | 0 | 0 | 0 | NA | 0 | 0 | 0 | 0.0 |
| | 6 | 0 | 0 | 0 | 0 | 0 | NA | 0 | 0 | 0.0 |
| OUTFLOWS: | | | | | | | | | 21,239 | |
| STARTING | | 9,124 | 2,081 | 7,609 | 2,425 | 0 | 0 | 21,239 | | |

*** RESULTS ***

| APPROACH | TURN MOVEMENT | BY COUNT | FY FORECAST |
|---|---|---|---|
| NORTH | LEFT | 3,500 | 1,615 |
| BOUND | THRU | 700 | 455 |
| | RIGHT | 800 | 279 |
| SOUTH | LEFT | 500 | 384 |
| BOUND | THRU | 1,000 | 458 |
| | RIGHT | 1,800 | 1,830 |
| EAST | LEFT | 700 | 1,149 |
| BOUND | THRU | 7,900 | 6,946 |
| | RIGHT | 3,400 | 1,784 |
| WEST | LEFT | 600 | 183 |
| BOUND | THRU | 8,400 | 5,679 |
| | RIGHT | 500 | 477 |

## APPENDIX E

### Turning Movement Procedures.

This appendix is a condensation of Chapter 8 of the User's Guide contained in NCHRP Report 255.

**Introduction**

Turning movement data are often required for the planning and design of highway intersections and interchanges. Therefore, procedures have been developed to enable the analyst to develop these data from sources and various uses. This appendix summarizes the procedures documented in "Highway Traffic Data For Urbanized Area Project Planning and Design," NCHRP Report 255, pp. 102-114.

Example problems to illustrate the five calculations involved are included at the end of this appendix.

**Scope**

The methodologies covered are as follows:

* Factoring procedure
* Iterative procedure
* Directional volume method of iterative procedure
* Nondirectional volume method of iterative procedure
* "T" intersection procedure
* Directional turning movement method of "T" intersection procedure
* Nondirectional turning movement method of "T" intersection procedure

## FACTORING PROCEDURE

**Introduction**

The discrepancy between a base year count and a base year assignment is assumed to be the same magnitude in the future year. Given this base, the future year turning movements can be modified by comparing the relative ratios or differences between base year link or turning volumes.

**Input Data Requirement**

The following directional or nondirectional data are required for both the ratio or difference procedures:

(1) Future year turning movement forecast
(2) Base year turning movement assignment
(3) Base year turning movement counts

**Ratio Method**

Each turning movement in the future assignment is factored by the ratio of the base year actual traffic count to the base year assignment.

$$V_{ri} = F_i * (B_{ci} / B_{ai})$$

where:

$V_{ri}$ = ratio adjusted future year volume for turning movement i;
$F_i$ = future year forecasted volume for turning movement i;
$B_{ci}$ = base year traffic count for turning movement i; and
$B_{ai}$ = base year assigned volume for turning movement i.

Each turning movement is adjusted separately and then summed to produce the adjusted total approach volumes.

**Difference Method**

Each turning movement in the future year assignment is factored by the difference between the base year actual traffic count and the base year assignment.

$$V_{di} = F_i + (B_{ci} - B_{ai})$$

where:

$V_{di}$ = difference adjusted future year volume for turning movement i;
$F_i$ = future year forecasted volume for turning movement i;

**FACTORING PROCEDURE (continued)**

**Difference Method (continued)**

$B_{ci}$ = base year traffic count for turning movement i; and
$B_{ai}$ = base year assigned volume for turning movement i.

Each turning movement is adjusted separately and then summed to produce an adjusted total approach volume.

**Combined Method**

$V_{fi} = (V_{ri} + V_{di}) / 2$

where:

$V_{ri}$ = ratio adjusted future year volume for turning movement i;
$V_{di}$ = difference adjusted future year volume for turning movement i; and
$V_{fi}$ = final averaged future year volume for turning movement i.

This averaged method tends to reduce the extremes experienced by the individual methods.

**Special Consideration: Lack Of Base Year Turning Volumes**

If base year turning volumes are not available, approach link volumes may be substituted for $B_{ci}$ and $B_{ai}$ in the ratio method only. This technique will not produce an adjustment that is as specific as that derived by comparing individual base year turning movements.

$V_{ri} = F_i * (B_{ci} / B_{ai})$

where:

$V_{ri}$ = ratio adjusted future year volume for turning movement i;
$F_i$ = future year forecasted volume for turning movement i;
$B_{ci}$ = base year actual approach volume (link volume) for turning movement i; and
$B_{ai}$ = base year assigned approach volume (link volume) for turning movement i.

Note that the difference method cannot be used with base year link volumes because the total difference between actual and assigned link volumes cannot be added to each individual turning movement.

## DIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE

**Introduction**

The directional volume method proceeds through an iterative computational technique to produce a final set of future year turning volumes. The computations involve alternatively balancing the rows (inflows) and columns (outflows) of a turning movement matrix until an acceptable convergence is obtained. Normally, a maximum of six to ten iterations requiring one or two person-hours should suffice.

**Input Data Requirement**

The following input data are required:

* Future year directional link volumes
* Either base year actual or assigned directional turning movements; initial estimate of future year directional turning movements.

The base year data preferably would be actual turning movement counts, but turning data from a base year assignment could also be used. In lieu of base year data, the analyst must make an initial estimate of future year turning percentages based on an examination of adjacent land uses or the turning movements at similar intersections.

**Directions for Use**

The directional volume method consists of five steps, and the following notations are used in the calculations:

n = number of links emanating from the intersection;
$O_{ib}$ = base year (b) inflow to the intersection on link i;
$O_{if}$ = future year (f) inflow to the intersection on link i;
$D_{jb}$ = base year (b) outflow from the intersection on link j;
$D_{jf}$ = future year (f) outflow from the intersection on link j;
$T_{ijb}$ = base year (b) traffic flow entering through link i and leaving link j;
$T_{ijf}$ = future year (f) traffic flow entering through link i and leaving link j;
$P_{ijf}$ = future year (f) estimated percentage of traffic flow from link i to link j; and
* = adjusted values in each iteration.

## DIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE (continued)

**Step 1 - Construct Initial Turning Movement Matrix**

This step involves constructing an initial matrix of turning movements to be used in the iterations. First, construct a turning movement matrix of base year turning volumes ($T_{ijb}$). Next, insert the row and column totals. The row totals should represent inflows ($O_{ib}$). The column totals should represent outflows ($D_{jb}$). This is shown below.

| | | | | | |
|---|---|---|---|---|---|
| | | Columns (outflows) $D_{ib}$ | ($D_{if}$) | | |
| Rows | X | X | X | X | Base Year |
| (inflows) | X | $T_{ijb}$ | | X | Turn |
| $O_i$ ($O_{ib}$) | X | | | X | Movements |
| | X | X | X | X | |

The sum of the T across each row and each column should equal to the $O_{ib}$ and $D_{jb}$ respectively.

**Step 2 - Perform the First Row Iteration**

In the matrix, replace the base year inflows ($O_{ib}$) with the future year inflow ($O_{if}$). Then, adjust each individual turning movement according to the following:

$$T_{ijf}^{*} = (O_{if} / O_{ib}) * T_{ijb}$$

where $T_{ijf}^{*}$ is the adjusted future volume for this iteration.

Construct a new matrix consisting of the $T_{ijf}^{*}$ and $O_{if}$. Now calculate the new $D_{jf}^{*}$ by summing the $T_{ijf}^{*}$ in each column j;

$$D_{jf}^{*} = \quad T_{ijf}^{*}$$

The matrix at this stage is shown below.

| | | | | |
|---|---|---|---|---|
| | | $D_{if}$ | | |
| | X | X | X | X |
| $O_{if}$ | X | $T_{ijf}^{*}$ | | X |
| | X | | | X |
| | X | X | X | X |

## DIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE (continued)

**Step 2 (continued)**

The $D_{jf}^*$ should be compared with the desired $D_{jf}$ from step 1. If the difference between these values is acceptable to the analyst, then the procedure is complete. Typically, a difference of $\pm$10% is considered to be acceptable. If a large discrepancy is apparent, then a further iteration(s) is required.

**Step 3 - Perform the First Column Iteration**

Replace the outflows ($D_{jf}^*$) with the original $D_{jf}$. Then adjust each individual movement according to the following:

$$T_{ijf}^{*\,new} = (D_{jf} / D_{jf}^*) * T_{ijf}^{*\,old}$$

where:

$T_{ijf}^{*\,old}$ = $T_{ijf}^*$ value in the matrix developed in step 2, and
$T_{ijf}^{*\,new}$ = adjusted $T_{ijf}$ after column iteration.

Next, construct a new matrix consisting of the $T_{ijf}^{*\,new}$ and $D_{jf}$. Then calculate the adjusted $O_{if}^*$ by summing the $T_{ijf}^{*\,new}$ in each row.

$$O_{if}^* = \quad T_{ijf}^{*\,new}$$

The $O_{if}^*$ should be compared with the original $O_{if}$ to check the acceptability of the difference between these values. Typically, a value of $\pm$10% is considered to be acceptable. If a large discrepancy is apparent, continue with a further iteration(s).

**Step 4 - Repeat Row Iteration**

If needed, repeat the Step 2 procedures for row iterations; thus, calculating new values for $T_{ijf}^{*\,new}$ and $D_{jf}^*$. Then compare $D_{jf}^*$ with $D_{jf}$.

**Step 5 - Repeat Column Iteration**

If needed after step 4, repeat the step 3 column iteration procedure. Calculate new values for $T_{ijf}^{*\,new}$ and $O_{if}^*$. Then compare $O_{if}^*$ with $O_{jf}$.

The $T_{ijf}^*$ value in the final iteration matrix will represent the final adjusted directional turning and thru movements.

**Example**

Example 2 demonstrates the directional volume method of iterative procedure. A microcomputer routine using Lotus 1-2-3 is available for this method.

## NONDIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE

**Introduction**

The nondirectional volume method produces two-way turning volumes and an estimate of the total vehicle turning percentage. Turning movements at an intersection should be some function of the attractions and productions each direction of travel offers.

The method provides a five-step sequence and may have to be performed iteratively to achieve a balanced distribution of turning and thru movements. The number of iterations will vary, but three to four iterations requiring one to three person-hours will be sufficient.

**Input Data Requirement**

Nondirectional link volumes (i.e., total both directions) on each approach are required input data for this method.

**Directions for Use**

The five-step methodology for the nondirectional volume method is described below.

**Step 1 - Estimate Total Turning Percentage**

The first step is to determine the percentage of total inflowing traffic which turns (either right or left). The turning percentage value must normally be estimated based on the unique characteristics of the intersection and comparable intersections from other parts of the urban area.

If the actual signal green times given to individual turning movements are known at the subject intersection, these values can be used instead of the estimated percentage for the entire intersection.

This turning movement percentage is estimated relative to the sum of only inflowing (i.e., one direction) volume. The inflowing volume equals one-half of the total nondirectional volume.

**Step 2 - Calculate the Relative Weight of Each Intersection Approach**

Calculate the relative weight of each intersection approach. Sum all nondirectional volumes on all the intersection approaches. Express the volume on a particular approach as a proportion of total volume. The proportions (or relative weight) on all approaches must sum to 1.00.

## NONDIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE (continued)

**Step 3 - Perform Initial Allocation of Turns**

This step involves allocating the volume in each approach to the other intersection approaches. Multiply the total volume on an approach by the relative weights, as computed in Step 2 for the remaining approaches which involve turns. This calculation should be performed for each intersection approach to produce turns to the other approaches.

**Step 4 - Adjust Turning Volumes Based on Turning Percentage**

The total volume of turns generated in Step 3 will typically exceed the likely volume of turns at the intersection. To adjust the step 3 estimates, a turning adjustment needs to be imposed. The adjustment involves the following computations:

(a) Write down the total inflowing volume (Step 1)
(b) Write down the total turn percentage (step 2)
(c) Compute total expected volume of turns as (a) x (b)
(d) Sum the turning volume calculated during Step 3
(e) Adjust the individual turns from Step 3 using either a difference method or ratio method

Difference method: $V_e = (V_c - V_d) / 4$
Ratio method: $R_e = V_c / V_d$

where:

$V_e$ = volume to be subtracted from each turning volume
$V_c$ = turning volume from Step 4(c)
$V_d$ = turning volume from Step 4(d)
$R_e$ = ratio to be multiplied by each turning volume

At the end of this step, the total volume of turns at the intersection will be equal to the expected volume total from Step 1.

**Step 5 - Balance the Approach Volumes and Adjusted Turning Volumes**

Typically the preceding steps will yield a turning movement estimate that conforms to the estimated turning percentage established in Step 1. However, it is possible, even likely, that the method will not yield an intersection scenario that accounts for all the traffic traversing the intersection.

To test for this situation, take each approach of the intersection and do the following:

## NONDIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE (continued)

**Step 5 (continued)**

(a) Write down the total approach volume
(b) Subtract the turns made to/from that approach from cross streets
(c) Add the turns made to/from the approach on the opposite side of the intersection

If the intersection clears all traffic, the total volume on the opposing approach of the intersection should equal the volume estimated from the above test. If these volumes do not correspond, out-of-balance numbers need to be adjusted to bring the analysis into equilibrium.

Two situations are normally encountered in this analysis:

(a) The opposite intersection approaches show a greater difference in adjusted volume (Step 5) than was evident in the original volumes (Step 2).
(b) The two opposing intersection approaches having adjusted volumes (Step 5) are closer to each other than was evident in the original volume (Step 2).

In the first situation, iterating the entire procedure from Step 2 using the new approach volumes will narrow the volume difference between two opposing intersection approaches.

The second situation in which the differences in volume on opposing approaches needs to be increased is more complicated. The following computations will provide an adjustment which will increase the difference between the opposing volumes.

(a) Sum the volumes on the two opposing approaches using the original volumes input at the outset of the analysis (Step 2).
(b) Determine the proportion of this volume (a) represented by each of the two opposing approaches. This must sum up to 1.00.
(c) Determine the approach volume difference between the adjusted and the original estimates.
(d) Multiply the proportions (b) by the volume difference (c). Add/subtract this number to/from the calculated volumes as appropriate.

**NONDIRECTIONAL VOLUME METHOD OF ITERATIVE PROCEDURE (continued)**

**Step 5 (continued)**

The above adjustments should be applied to each intersection approach in order to insure that the approach volumes are in scale relative to the completed turning volumes.

**Example**

Example 3 demonstrates the nondirectional volume method of iterative procedure. A microcomputer routine using Lotus 1-2-3 is available for this method.

## DIRECTIONAL TURNING MOVEMENT METHOD OF "T" INTERSECTION PROCEDURE

**Introduction**

A unique solution for directional volumes at "T" intersections cannot be determined from directional volumes alone. However, knowledge of one directional volume will produce a unique solution for all other directional volumes.

**Basis for Development**

Because a "T" intersection has only six directional movements involved, simple mathematics can be used to derive equations to aid in the solution. A total of five independent equations are available to solve for six unknown volumes. Therefore, one movement must be known or estimated before the five movements can be calculated.

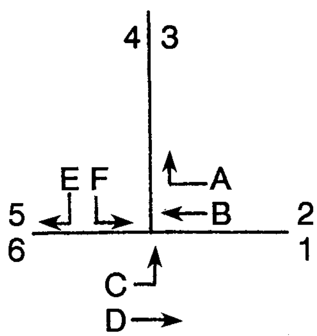
**Input Data Requirements**

Six directional link volumes are required to input to this method. In addition, one of the six turning volumes must be known or estimated.

**Directions for Use**

If one turning volume or one through movement is known or can be estimated, the analyst can calculate the remaining volumes. Five independent equations can be constructed. The figure below shows a typical solution with unknown volumes A, B, C, D, and E, while F is assumed to be known, as are the link volumes 1 through 6. The following equations are possible:

E = Volume 4 - F
A = Volume 5 - E
B = Volume 2 - A
C = Volume 3 - B
D = Volume 6 - C




Substituting for the link volumes and for F, the volumes A through E are calculated sequentially.

**Example**

Example 4 is provided to demonstrate the directional turning movement method of "T" intersection procedure. A microcomputer routine using Lotus 1-2-3 is available for this method.

## NONDIRECTIONAL TURNING MOVEMENT METHOD OF "T" INTERSECTION PROCEDURE

**Introduction**

Nondirectional turn volumes can be easily computed if nondirectional link volumes on the three approaches are known.

**Basis for Development**

The nondirectional method is mathematically based on algebraic relationships. The two unknown turning volumes can be directly obtained from two independent equations.

**Input Data Requirements**

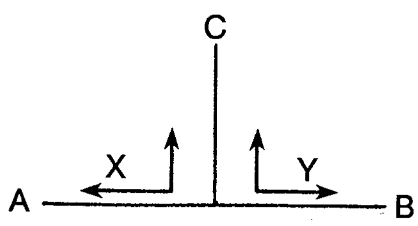
Input data required for this method are nondirectional link volumes for each of the three approaches.

**Directions for Use**

Referring to the figure below for notations, the following equations are used:

$$X = (A - B + C) / 2$$
$$Y = (C - A + B) / 2$$

where A, B, and C are link volumes and X and Y are desired turning movements:




**"T" intersection with nondirectional turning movements.**

**Example**

Example 5 is provided to demonstrate the nondirectional turning movement method of the "T" intersection procedure. A microcomputer routine using Lotus 1-2-3 is available for this method.

## EXAMPLES OF TURNING MOVEMENT PROCEDURES

**Introduction**

Five examples are provided in order to demonstrate the turning movement procedures:

Example 1 - Factoring procedure
Example 2 - Directional volume method for iterative procedures
Example 3 - Nondirectional volume method for iterative procedures
Example 4 - Nondirectional turning movement method
Example 5 - Directional turning movement method

## EXAMPLE 1 - FACTORING PROCEDURE

**Problem**

Determine year 2000 turning movements at the intersection of Texas Avenue and University Drive in the City of College Station using factoring procedure.

**Given**

Base year (BY) turning movement count (1985)
Base year (BY) turning movement assignment (1985)
Future year (FY) turning movement forecast (2000)

**Method**

Ratio: $V_R$ = FY forecasted volume * (BY count / BY assignment)

Difference: $V_D$ = FY forecasted volume + (BY count - BY assignment)

Combined: $V_C$ = $(V_R + V_D)$

**Results**

Future Year Turning Movement

| Approach | Turn Movement | BY Count | BY Assignment | | Adjusted Future Volume Rai. | Dif. | Com. |
|---|---|---|---|---|---|---|---|
| NB | Left | 36 | 447 | | 428 | 441 | 435 |
| | Thru | 805 | 1666 | 2537 | 934 | 1037 | 1004 |
| | Right | 399 | 424 | | 537 | 546 | 542 |
| SB | Left | 148 | 195 | | 199 | 215 | 207 |
| | Thru | 703 | 1611 | 2175 | 816 | 962 | 889 |
| | Right | 133 | 369 | | 154 | 192 | 173 |
| EB | Left | 422 | 375 | | 490 | 482 | 486 |
| | Thru | 763 | 799 | 1755 | 1027 | 1039 | 1033 |
| | Right | 249 | 581 | | 289 | 343 | 316 |
| WB | Left | 433 | 436 | | 541 | 542 | 542 |
| | Thru | 535 | 849 | 1469 | 669 | 747 | 708 |
| | Right | 164 | 184 | | 205 | 210 | 208 |

## EXAMPLE 2 - DIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES

**Problem**

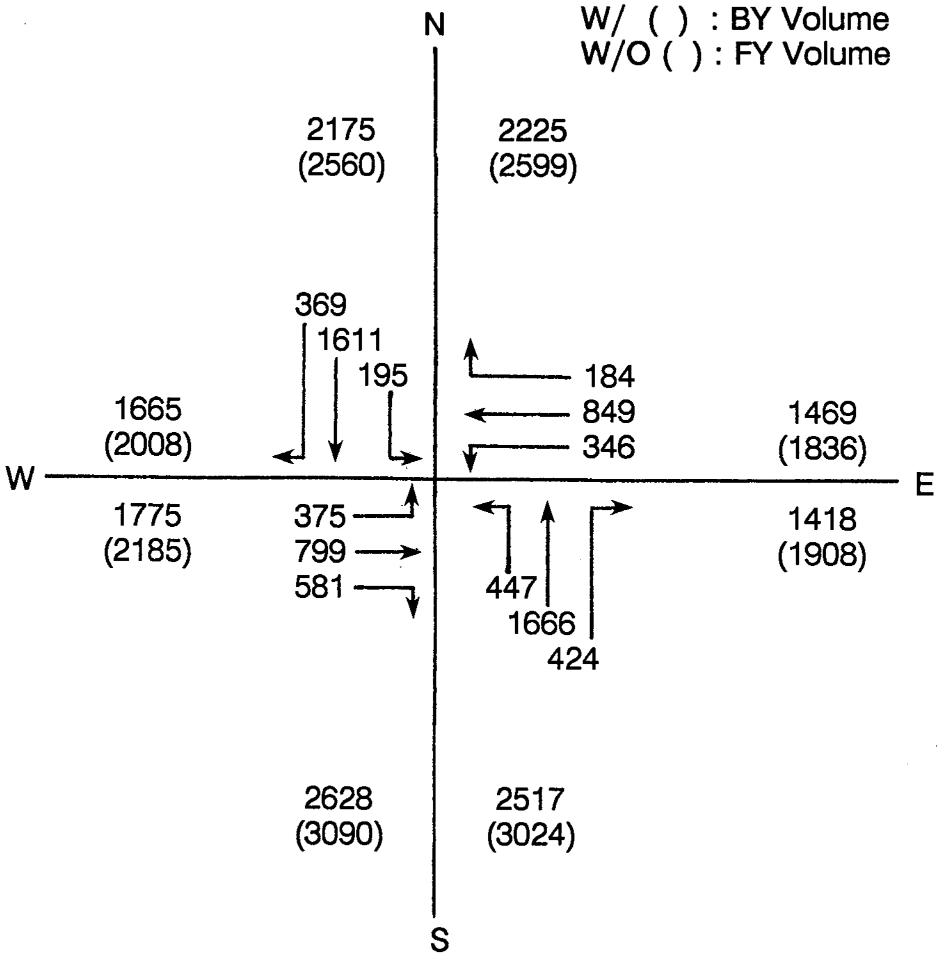
Determine year 2000 turning movement at the intersection of Texas Avenue and University Drive in the City of College Station using directional volume method of iterative procedure.

**Given**

Base year (BY) turning movement (1985)
Future year (FY) directional link volume (2000)

**Directional Intersection Volumes**

P.M. Peak Hour
5:30 to 6:30



**EXAMPLE 2 - DIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES (continued)**

**Step 1 - Construct Initial Turning Movement Matrix**

W/ ( ) : FY Vol.
W/O ( ) : BY Vol.

| OF / IF | (2599) 2225 | (3090) 2628 | (1908) 1818 | (2008) 1665 |
|---|---|---|---|---|
| N (2560) 2175 | 0 | 1611 | 195 | 369 |
| S (3024) 2537 | 1666 | 0 | 424 | 447 |
| E (1836) 1469 | 184 | 436 | 0 | 849 |
| W (2185) 1755 | 375 | 581 | 799 | 0 |

**Step 2 - Perform the First Row Iteration**

Calculate the adjusted future volume for this intersection.

| OF / IF | N 2683 | S 3164 | E 1730 | W 2028 ($D_{jf}^*$) |
|---|---|---|---|---|
| N 2560 | 0 | 1896 | 230 | 434 |
| S 3024 | 1986 | 0 | 505 | 533 |
| E 1836 | 230 | 545 | 0 | 1061 |
| W 2185 | 467 | 723 | 995 | 0 |
| ($O_{if}^*$) | | | | |

$T_{ijf}^* = O_{if} / O_{ib} * T_{ijb}$

where

$T_{ijf}^*$ = adjusted future volume entering link i and leaving link j;
$T_{ijb}^*$ = base year traffic volume entering link i and leaving link j;
$O_{if}$ = future year inflow to the intersection on link i; and
$O_{ib}$ = base year inflow to the intersection on link i.

**EXAMPLE 2 - DIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES (continued)**

**Step 2 (continued)**

Compare

| | $D_{jf}^*$ | $D_{jf}$ | |
|---|---|---|---|
| N | 2683 | 2599 | + 3 % |
| S | 3164 | 3090 | + 2 % |
| E | 1730 | 1908 | - 9 % |
| W | 2028 | 2008 | + 1 % |
| Total | 9605 | 9605 | |

where:

$D_{jf}^*$ = adjusted future year outflow from the intersection on link j;
$D_{jf}$ = future year outflow from intersection on link j.

**Step 3 - Perform the First Column Iteration**

Calculate the new adjusted future volume for this intersection.

| IF \ OF | N 2599 | S 3090 | E 1908 | W 2008 | ($D_{jf}$) |
|---|---|---|---|---|---|
| N 2539 | 0 | 1852 | 257 | 430 | |
| S 3016 | 1923 | 0 | 565 | 528 | |
| E 1806 | 223 | 532 | 0 | 1051 | |
| W 2244 | 453 | 706 | 1085 | 0 | |
| ($O_{if}^*$) | | | | | |

$T_{ijf}^{*\,new} = D_{jf} / D_{jf}^* * T_{ijf}^{*\,old}$

where:

$T_{ijf}^{*\,new}$ = adjusted $T_{ijf}$ value after column iteration;
$T_{ijf}^{*\,old}$ = $T_{ijf}$ value after column iteration;
$D_{jf}$ = future year outflow from the intersection on link j;
$D_{jf}^*$ = adjusted D.

**EXAMPLE 2 - DIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES (continued)**

**Step 3 (continued)**

| Compare | $O_{if}^{*}$ | $O_{if}$ | |
|---|---|---|---|
| | N 2539 | 2560 | - 1.0 % |
| | S 3016 | 3024 | + 0.3 % |
| | E 1806 | 1836 | - 2.0 % |
| | W 2244 | 2185 | + 3.0 % |
| Total | 9605 | 9605 | |

where:

$O_{if}^{*}$ = adjusted future year inflow to the intersection on link i;
$O_{if}$ = future year inflow to the intersection on link i.

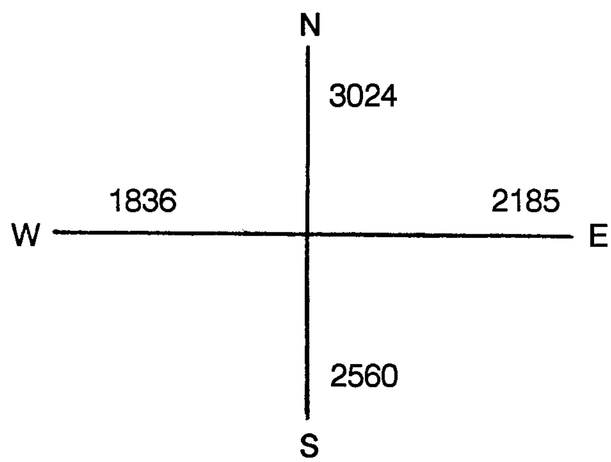
**EXAMPLE 3 - NONDIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES**

**Problem**

Determine year 2000 turning movement at the intersection of Texas Avenue and University Drive in the City of College Station using nondirectional volume method of iterative procedure.

**Given**

Future year (FY) nondirectional link volume (2000)




**Step 1 - Estimate Total Turning Percentage**

Sum = 3024 + 2560 + 2185 + 1836 = 9786

Total Inflowing Flow = 9786 / 2 = 4893

Assume % of Turning Movement Volume; 20 %

Turning Volume = 979
Through Volume = 3914

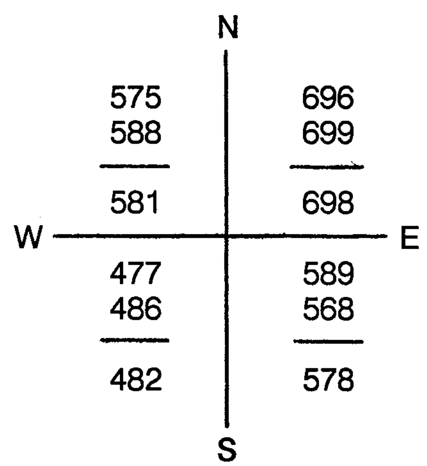
**Step 2 - Calculate Relative Weight of Total Turning Percentage**

Approach E: 2185 / 9786 = 0.23
Approach N: 3024 / 9786 = 0.32
Approach W: 1836 / 9786 = 0.19
Approach S: 2560 / 9786 = 0.26

**EXAMPLE 3 - NONDIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES**
(continued)

**Step 3 - Perform Initial Allocation of Turns**

| From Approach | To Approach | |
|---|---|---|
| E | N | 2185 * .032 = 699 |
| | S | 2185 * 0.26 = 568 |
| N | E | 3024 * 0.23 = 696 |
| | W | 3024 * 0.19 = 575 |
| W | N | 1836 * 0.32 = 588 |
| | S | 1836 * 0.26 = 477 |
| S | E | 2560 * 0.23 = 589 |
| | W | 2560 * 0.19 = 486 |




**Step 4 - Adjust Turn Volumes Based on Turning Percentage**

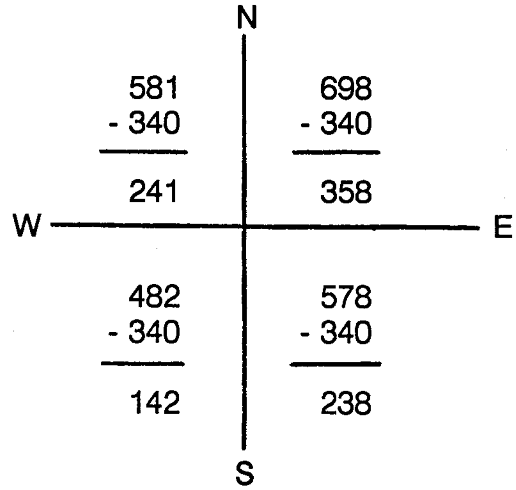
Total Expected Volume of Turns = 4897 * 0.2 = 979

Sum of Turns from Step 3
Sum = 698 + 581 + 482 + 578 = 2339

Adjustment
Difference Method : (2339 - 979) / 4 = 340
Ratio Method : 979 / 2339 = 0.42

**EXAMPLE 3 - NONDIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES (continued)**

**Step 4 (continued)**




**Step 5 - Balance Volume and Adjusted Turn Volumes**

Subtract the turns made to/from that approach from the cross street and add the turns made to/from the approach on the opposite side of the intersection.

E: 2185 - 358 - 238 + 241 + 142 = 1972
N: 3024 - 358 - 241 + 142 + 238 = 2805
W: 1836 - 241 - 142 + 358 + 238 = 2049
S: 2560 - 142 - 238 + 241 + 358 = 2779

| | Original Volume Difference | Adjusted Volume Difference | Balancing |
|---|---|---|---|
| Approach E/W | 2185 - 1836 = 349 | 2049 - 1972 = 77 | Increase Dif. |
| Approach N/S | 3024 - 2560 = 464 | 2779 - 2049 = 730 | Decrease Dif. |

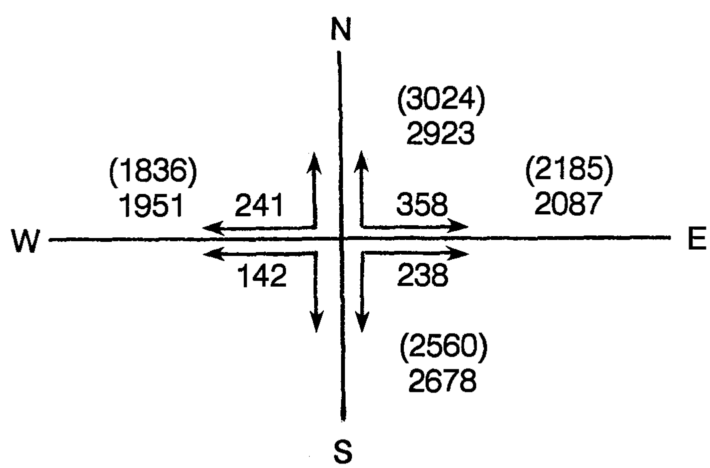
**EXAMPLE 3 - NONDIRECTIONAL VOLUME METHOD FOR ITERATIVE PROCEDURES (continued)**

**Step 5 (continued)**

| Approach E/W | Approach N/S |
|---|---|
| 1836 + 2185 = 4021 | 3024 + 2560 = 5584 |
| E : 2185 / 4021 = 0.54<br>W : 1836 / 4021 = 0.46 | N : 3024 / 5584 = 0.54<br>S : 2560 / 5584 = 0.46 |
| E : 2185 - 1972 = 213<br>W : 1836 - 2049 = -213 | N : 3024 - 2805 = 219<br>S : 2560 - 2779 = -21 |
| E : 0.54 * 213 = 115 (Add)<br>W : 0.46 * 213 = 98 (Sub.) | N : 0.54 * 216 = 118 (Sub.)<br>S : 0.46 * 219 = 101 (Add) |

**Results**

W/ ( ) : Existing Volume
W/O ( ) : Refined Volume



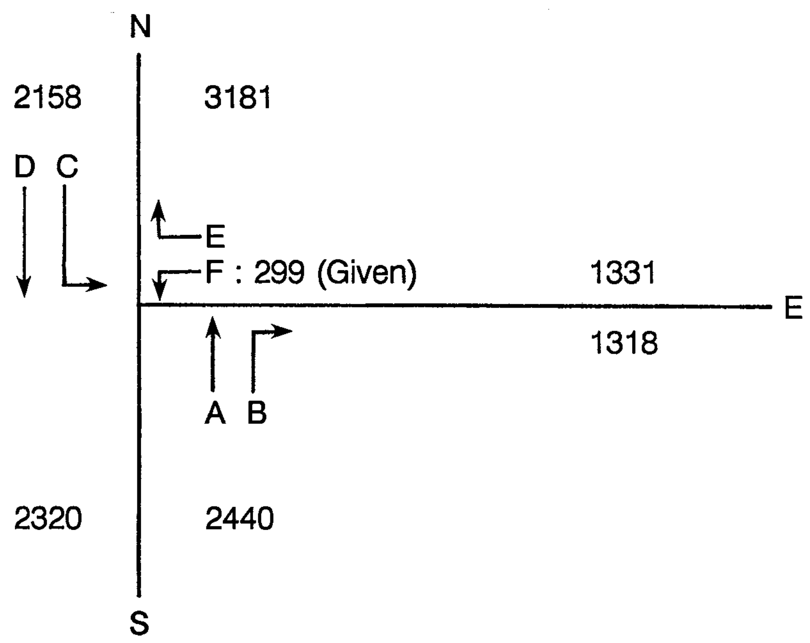
## EXAMPLE 4 - NONDIRECTIONAL TURNING MOVEMENT METHOD

**Problem**

Determine turning movements at "T" intersection of Texas Avenue and Harvey Road in the City of College Station using directional "T" intersection procedure.

**Given**

6 directional link volumes (1985)
1 directional turning movement (1985)




**Method**

E = Volume 4 - F where F is known (F = 299)
A = Volume 5 - E
B = Volume 2 - A
C = Volume 3 - B
D = Volume 6 - C

**Calculations**

E : 1331 - 299 = 1032

A : 3181 - 1032 = 295

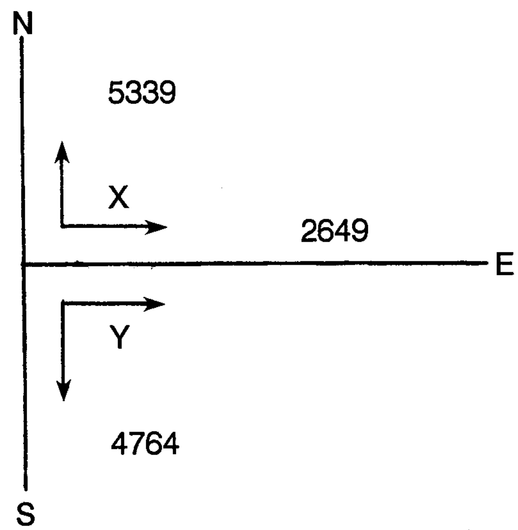
C : 1318 - 295 = 1023

D : 2158 - 1023 = 1135

## EXAMPLE 5 - DIRECTIONAL TURNING MOVEMENT METHOD

**Problem** Determine turning movements at the intersection of Texas Avenue and Harvey Road in the City of College Station using nondirectional "T" intersection procedure.

**Given** Nondirectional link volume (1985)




**Calculations** X = (N - S + E) / 2 = 1612

Y = (E - N + S) / 2 = 1037

# APPENDIX F

## Development of Theoretical Turning Movements.

## DEVELOPMENT OF THEORETICAL TURNING MOVEMENTS

This appendix presents a method for producing theoretical turning volumes. The calculation consists of five sequential steps. The volume (counted or assigned) on each approach of the intersection is the only data necessary to apply the procedure. The following are symbols and steps used.

### Directions for Use

$\alpha_1$ = left movement proportion from minor roadway;
$\alpha_2$ = thru movement proportion from minor roadway;
$\alpha_3$ = right movement proportion from minor roadway;
$\beta_1$ = left movement proportion from major roadway;
$\beta_2$ = through movement proportion from major roadway;
$\beta_3$ = right movement proportion from major roadway;
$I_i$ = inflow link volume for direction i (i = N,S,E,W);
$V_1$ = sum of major inflow link volumes;
$V_2$ = sum of minor inflow link volumes;
r = $V_1$ / $V_2$, ratio of sums of major and minor roadway approach volumes.

### Development of Theoretical Turning Volumes.

The method for developing theoretical turning volumes is composed of five sequential steps. The following is the procedure developed for the method:

**Step 1** --- Calculate ratio of sums of major and minor roadway inflow link volumes.

Assuming that N-S and E-W are directions of major and minor roadways, respectively, $V_1 = I_n + I_s$, $V_2 = I_e + I_w$, and $r = V_1 / V_2$. This ratio is, therefore, greater than or equal to 1 since it was calculated by dividing the sum of major roadway approach volumes with the sum of minor roadway approach volumes.

**Step 2** --- Develop equations that show the relationships between turning movements.

Based on a 24-hour assignment, it was assumed that the left (or right) turn volume of a roadway is the same with the right- (or left-) turn volume of a crossing roadway. In addition, the following assumptions were used to develop equations: (1) through movement proportions of a minor roadway ($\alpha 2$) is a reciprocal of the approach volume ratio, r, calculated in Step 1; (2) the ratio of left-turn proportions, $\alpha 1$ and $\beta 1$, of minor roadways and major roadways is same with the approach volume ratio. These assumptions were reasonable since the higher traffic volumes on a roadway would attract the higher turning movements from crossing roadways. The following are the procedures that develop the equations that show the relationships between turning movements:

$I_i = \alpha_1 \times I_i + \alpha_2 \times I_i + \alpha_3 \times I_i$, and

$I_i = \beta_1 \times I_i + \beta_2 \times I_i + \beta_3 \times I_i$.

Therefore,

$\alpha_1 + \alpha_2 + \alpha_3 = 1$ ---------------- Equ. (1)

$\beta_1 + \beta_2 + \beta_3 = 1$ ---------------- Equ. (2).

Also,

$I_e \times \alpha_1 = I_s \times \beta_3$;
$I_e \times \alpha_3 = I_n \times \beta_1$;
$I_w \times \alpha_1 = I_n \times \beta_3$; and
$I_w \times \alpha_3 = I_s \times \beta_1$.

From above equations,

$I_e + I_w = \beta_3/\alpha_1 (I_n + I_s)$

$(I_n + I_s)/(I_e + I_w) = \alpha_1 / \beta_3$; and

$I_e + I_w = \beta_1/\alpha_3 (I_n + I_s)$

$(I_n + I_s)/(I_e + I_w) = \alpha_3 / \beta_1$.

Since

$(I_n + I_s)/(I_e + I_w) = V_1 / V_2$,

$(I_n + I_s)/(I_e + I_w) = \alpha_1 / \beta_3$, and

$(I_n + I_s)/(I_e + I_w) = \alpha_3 / \beta_1$;

$\beta_3 / \alpha_1 = V_1 / V_2 = r$ ------------- Equ. (3)

$\beta_1 / \alpha_3 = V_1 / V_2 = r$ ------------- Equ. (4)

$\alpha_1 \times \beta_1 = \beta_3 \times \alpha_3$ ----------------- Equ. (5).

From the assumptions,

$$\alpha_2 = 1/n \text{ ------------------------ Equ. (5)}$$

$$\alpha_1/\beta_1 = n \text{ ----------------------- Equ. (6).}$$

**Step 3** --- Identify the proportion of each turn movement using the approach volume ratio (r).

Using equations 1 through 6, the proportion of each turn movement was developed as follows:

$\alpha_1 = (n - 1) / 2n$
$\alpha_2 = 1 / n$
$\alpha_3 = (n - 1) / 2n$
$\beta_1 = (n - 1) / 2n^2$
$\beta_2 = (n^2 - n + 1) / n^2$
$\beta_3 = (n - 1) / 2n^2$.

There was, however, a limitation to apply to the equations above to calculate turning movement proportions. These equations' application for $r < 2.0$ resulted in unrealistic turning movement proportions. The equations could be applied, therefore, only to the case of $r \geq 2.0$. The turning movement proportions for $r < 2.0$ were developed using a different method. Those for $r < 2.0$ were calculated by interpolating the turning movement proportions calculated for $r \geq 2$.

**Step 4** --- Calculate proportions of turning movements for various r values.

The turning movement proportions for $r \geq 2$ were calculated using the equations developed in Step 3. Those calculated values were then used to calculate those for $r = 1$. The amount of increase and decrease between proportions calculated for each movement for integer r values was extrapolated to calculate the turning movement proportions for $r = 1$. Table 1 shows the results of calculation and interpolation for each integer r value and each movement. The turning movement percentages for $1 < r < 2$ were also calculated by interpolation between the values $r = 1$ and 2 (see Table 2).

Table 1. Turning Movement Proportions for Various r Values.

| r | Minor LT Pro.($\alpha_1$) | Minor TH Pro.($\alpha_2$) | Minor RT Pro.($\alpha_3$) | Maj. LT Pro.($\beta_1$) | Maj. TH Pro.($\beta_2$) | Maj.RT Pro.($\beta_3$) |
|---|---|---|---|---|---|---|
| 1.0 | .15 | .70 | .15 | .15 | .70 | .15 |
| 2.0 | .25 | .50 | .25 | .125 | .75 | .125 |
| 3.0 | .33 | .34 | .33 | .11 | .78 | .11 |
| 4.0 | .37 | .26 | .37 | .09 | .82 | .09 |
| 5.0 | .40 | .20 | .40 | .08 | .84 | .08 |
| 6.0 | .42 | .16 | .42 | .07 | .86 | .07 |
| 7-8 | .43-.44 | .12-.14 | .43-.44 | .06 | .88 | .06 |
| 9-10 | .44-.45 | .10-.12 | .44-.45 | .05 | .90 | .05 |
| : | : | : | : | : | : | : |
| : | : | : | : | : | : | : |
| 00 | .50 | 0.0 | .50 | 0.0 | 1.0 | 0.0 |

Table 2. Turning Movement Proportion for 1 < r < 2.

| r | Minor LT Pro.($\alpha_1$) | Minor TH Pro.($\alpha_2$) | Minor RT Pro.($\alpha_3$) | Maj. LT Pro.($\beta_1$) | Maj. TH Pro.($\beta_2$) | Maj. RT Pro.($\beta_3$) |
|---|---|---|---|---|---|---|
| 1.1 | .16 | .68 | .16 | .148 | .70 | .148 |
| 1.2 | .17 | .66 | .17 | .145 | .71 | .148 |
| 1.3 | .18 | .64 | .18 | .143 | .715 | .143 |
| 1.4 | .19 | .62 | .19 | .140 | .72 | .140 |
| 1.5 | .20 | .60 | .20 | .138 | .725 | .138 |
| 1.6 | .21 | .58 | .21 | .135 | .73 | .135 |
| 1.7 | .22 | .56 | .22 | .133 | .735 | .133 |
| 1.8 | .23 | .54 | .23 | .130 | .74 | .130 |
| 1.9 | .24 | .52 | .24 | .138 | .745 | .138 |

**Step 5** --- Calculate theoretical turning volume for each movement.

The theoretical turning volume for each movement is calculated by multiplying each approach volume and proportion of each turning movement developed in Step 5. A FORTRAN program was developed to use in calculating the turning movement proportions and volumes (see Appendix 1).

# APPENDIX G

## Counted Approach Volumes and Turning Movements, Turning Movements As A Percentage of Approach Volume, and Theoretical Percent Turning Movements.

COUNTED VOLUMES AND MOVEMENTS AS A PERCENTAGE OF APPROACH AND THEORETICAL TURN PERCENTAGES

| Intersection | App. Dir. | App. Vol. | Left Turn Count Vol. | Left Turn Count % | Left Turn Theor. % | Thru Movement Count Vol. | Thru Movement Count % | Thru Movement Theor. % | Right Turn Count Vol. | Right Turn Count % | Right Turn Theor. % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Higher Volume Intersections (Group A Intersections)** | | | | | | | | | | | |
| SEARS US 75 | N | 4313 | 82 | 1.9 | 3.5 | 4110 | 95.3 | 93.1 | 121 | 2.8 | 3.5 |
| | E | 352 | 153 | 43.5 | 46.3 | 137 | 38.9 | 7.5 | 62 | 17.6 | 46.3 |
| | S | 4360 | 83 | 1.9 | 3.5 | 4203 | 96.4 | 93.1 | 74 | 1.7 | 3.5 |
| | W | 296 | 59 | 19.9 | 46.3 | 144 | 48.7 | 7.5 | 93 | 31.4 | 46.3 |
| MAIN US 75 | N | 5932 | 552 | 9.3 | 9.6 | 4526 | 44.0 | 80.9 | 854 | 14.4 | 9.6 |
| | E | 1643 | 876 | 53.3 | 37.1 | 542 | 33.0 | 25.8 | 225 | 13.7 | 37.1 |
| | S | 5321 | 239 | 4.5 | 9.6 | 4746 | 89.2 | 80.9 | 335 | 6.5 | 9.6 |
| | W | 1255 | 217 | 17.3 | 37.1 | 552 | 44.0 | 25.8 | 486 | 13.7 | 37.1 |
| CHESTN AUSTIN | N | 6688 | 902 | 13.5 | 6.1 | 5584 | 83.5 | 87.8 | 200 | 3.0 | 6.1 |
| | E | 597 | 186 | 31.2 | 42.9 | 331 | 55.4 | 14.2 | 80 | 13.4 | 42.9 |
| | S | 6330 | 87 | 1.4 | 6.1 | 5811 | 91.8 | 87.8 | 430 | 6.8 | 6.1 |
| | W | 1248 | 244 | 19.6 | 42.9 | 319 | 25.6 | 14.2 | 684 | 54.8 | 42.9 |
| CRAWFO US 75 | N | 6606 | 6 | 0.1 | 6.5 | 6308 | 95.5 | 87.0 | 291 | 4.4 | 6.5 |
| | E | 814 | 446 | 54.8 | 42.3 | 334 | 41.0 | 15.4 | 34 | 4.2 | 42.3 |
| | S | 6539 | 7 | 0.1 | 6.5 | 6049 | 92.8 | 87.0 | 464 | 7.1 | 6.5 |
| | W | 1210 | 301 | 24.9 | 42.3 | 380 | 31.4 | 87.0 | 529 | 43.7 | 42.3 |
| MUNSON US 75 | N | 6608 | 7 | 0.1 | 2.1 | 6489 | 98.2 | 95.7 | 112 | 1.7 | 2.1 |
| | E | 297 | 62 | 20.9 | 47.8 | 69 | 23.2 | 21.6 | 166 | 55.9 | 47.8 |
| | S | 7195 | 7 | 0.1 | 2.1 | 7036 | 97.8 | 95.7 | 151 | 2.1 | 2.1 |
| | W | 297 | 134 | 45.1 | 47.8 | 64 | 21.6 | 21.6 | 99 | 33.3 | 47.8 |
| HULL US 75 | N | 6303 | 290 | 6.4 | 5.7 | 5874 | 93.2 | 88.6 | 139 | 2.2 | 5.7 |
| | E | 690 | 133 | 19.3 | 43.5 | 290 | 42.0 | 13.1 | 267 | 38.7 | 43.5 |
| | S | 7477 | 389 | 5.2 | 5.7 | 6699 | 89.6 | 88.6 | 389 | 5.2 | 5.7 |
| | W | 1114 | 358 | 32.2 | 43.5 | 348 | 31.2 | 13.1 | 407 | 36.6 | 43.5 |
| HERON US 75 | N | 6200 | 62 | 1.0 | 2.3 | 6113 | 98.6 | 95.5 | 25 | 0.4 | 2.3 |
| | E | 249 | 70 | 28.1 | 47.6 | 97 | 39.0 | 4.8 | 82 | 32.9 | 47.6 |
| | S | 6637 | 93 | 1.4 | 2.3 | 6391 | 96.3 | 95.5 | 153 | 2.3 | 2.3 |
| | W | 364 | 221 | 60.7 | 47.6 | 63 | 17.3 | 4.8 | 80 | 22.0 | 47.6 |
| US 69 US 75 | N | 5636 | 62 | 1.1 | 8.7 | 4678 | 83.0 | 82.6 | 169 | 3.0 | 8.7 |
| | E | 2369 | 843 | 35.6 | 38.8 | 199 | 8.4 | 22.5 | 1326 | 56.0 | 38.8 |
| | S | 6293 | 1189 | 18.9 | 8.7 | 4914 | 78.1 | 82.6 | 189 | 3.0 | 8.7 |
| | W | 314 | 90 | 28.7 | 38.8 | 177 | 56.4 | 22.5 | 47 | 14.9 | 38.8 |
| FALLON US 75 | N | 7719 | 255 | 3.3 | 4.1 | 7240 | 93.8 | 91.8 | 224 | 7.9 | 4.1 |
| | E | 801 | 482 | 60.2 | 45.5 | 47 | 5.9 | 9.0 | 272 | 33.1 | 45.5 |
| | S | 7530 | 324 | 4.3 | 4.1 | 6807 | 90.4 | 91.8 | 399 | 5.3 | 4.1 |
| | W | 574 | 366 | 63.9 | 45.5 | 46 | 8.0 | 9.0 | 162 | 28.1 | 45.5 |
| GALLAG US 75 | N | 7770 | 653 | 8.4 | 5.4 | 6962 | 89.6 | 89.2 | 155 | 2.0 | 5.4 |
| | E | 811 | 161 | 19.9 | 43.9 | 271 | 33.5 | 12.3 | 377 | 46.6 | 43.9 |
| | S | 7333 | 483 | 6.6 | 5.4 | 6467 | 88.2 | 89.2 | 381 | 5.2 | 5.4 |
| | W | 1043 | 440 | 42.2 | 43.9 | 327 | 31.4 | 12.3 | 275 | 26.4 | 43.9 |
| PEYTON US 75 | N | 9700 | 718 | 7.4 | 2.7 | 8836 | 91.1 | 94.6 | 146 | 1.5 | 2.7 |
| | E | 292 | 154 | 52.7 | 47.1 | 53 | 18.2 | 5.1 | 85 | 29.1 | 47.1 |
| | S | 8429 | 169 | 2.0 | 2.7 | 7932 | 94.2 | 94.6 | 328 | 3.9 | 2.7 |
| | W | 744 | 325 | 43.7 | 47.1 | 92 | 12.4 | 5.1 | 326 | 43.9 | 47.1 |
| GRANND US 75 | N | 9722 | 418 | 4.3 | 7.5 | 8419 | 86.6 | 84.9 | 884 | 9.1 | 7.5 |
| | E | 1641 | 871 | 53.1 | 40.8 | 530 | 32.3 | 18.5 | 240 | 14.6 | 40.8 |
| | S | 8439 | 675 | 8.0 | 7.5 | 6870 | 82.6 | 84.9 | 793 | 9.4 | 7.5 |
| | W | 1718 | 1034 | 60.2 | 40.8 | 503 | 29.3 | 18.5 | 180 | 10.5 | 40.8 |
| BROUGH US 75 | N | 10051 | 1397 | 13.9 | 6.8 | 8332 | 82.9 | 86.5 | 322 | 3.2 | 6.8 |
| | E | 1455 | 490 | 33.7 | 41.9 | 457 | 31.4 | 16.1 | 508 | 34.9 | 41.9 |
| | S | 7407 | 481 | 6.5 | 6.8 | 6889 | 93.0 | 86.5 | 37 | 0.5 | 6.8 |
| | W | 1849 | 113 | 6.1 | 41.9 | 456 | 24.7 | 16.1 | 1280 | 69.2 | 41.9 |

| Intersection | | App. Dir. | App. Vol. | Left Turn | | | Thru Movement | | | Right Turn | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Count | | Theor. | Count | | Theor. | Count | | Theor. |
| | | | | Vol. | % | % | Vol. | % | % | Vol. | % | % |
| **Lower Volume Intersections (Group B Intersections)** | | | | | | | | | | | | |
| MAURIE | FM 120 | N | 448 | 361 | 80.6 | 43.8 | 49 | 10.9 | 12.4 | 38 | 8.5 | 43.8 |
| | | E | 3004 | 48 | 1.6 | 5.4 | 2887 | 96.1 | 89.1 | 69 | 2.3 | 5.4 |
| | | S | 356 | 46 | 12.9 | 43.8 | 96 | 27.0 | 12.4 | 214 | 60.1 | 43.8 |
| | | W | 3467 | 118 | 3.4 | 5.4 | 2930 | 84.5 | 5.4 | 420 | 12.1 | 5.4 |
| FM 120 | TONE | N | 2424 | 1120 | 46.2 | 15.0 | 1241 | 51.2 | 70.0 | 63 | 2.6 | 15.0 |
| | | E | 1632 | 54 | 3.3 | 2.0 | 1408 | 86.3 | 96.0 | 170 | 10.4 | 2.0 |
| | | S | 1957 | 117 | 6.0 | 15.0 | 1542 | 78.8 | 70.0 | 297 | 15.2 | 15.0 |
| | | W | 2940 | 320 | 10.9 | 2.0 | 1414 | 48.1 | 96.0 | 1205 | 41.0 | 2.0 |
| WASHIG | TONE | N | 1733 | 849 | 49.0 | 16.0 | 236 | 13.6 | 68.0 | 648 | 37.4 | 16.0 |
| | | E | 955 | 485 | 50.8 | 5.0 | 373 | 39.1 | 90.0 | 96 | 10.1 | 5.0 |
| | | S | 638 | 183 | 28.7 | 16.0 | 324 | 50.8 | 68.0 | 131 | 20.5 | 16.0 |
| | | W | 1719 | 144 | 8.4 | 5.0 | 573 | 33.6 | 90.0 | 997 | 58.0 | 5.0 |
| MORTON | ARMSTR | N | 382 | 83 | 21.7 | 40.4 | 233 | 61.0 | 19.3 | 66 | 17.3 | 40.4 |
| | | E | 1692 | 80 | 4.7 | 7.8 | 1563 | 92.4 | 84.4 | 49 | 2.9 | 7.8 |
| | | S | 270 | 48 | 17.8 | 40.4 | 207 | 76.7 | 19.3 | 15 | 5.5 | 40.4 |
| | | W | 1690 | 41 | 2.4 | 7.8 | 1555 | 92.0 | 84.4 | 95 | 5.0 | 7.8 |
| MORTON | US 75 | N | 4243 | 615 | 14.5 | 8.5 | 3564 | 84.0 | 83.0 | 64 | 1.5 | 8.5 |
| | | E | 498 | 66 | 13.3 | 39.2 | 397 | 79.7 | 21.7 | 35 | 7.0 | 39.2 |
| | | S | 3830 | 31 | 0.8 | 8.5 | 3612 | 94.3 | 83.0 | 188 | 4.9 | 8.5 |
| | | W | 1251 | 215 | 17.2 | 39.2 | 372 | 29.7 | 21.7 | 664 | 53.1 | 39.2 |
| MAIN | HOUSTO | N | 1181 | 141 | 11.9 | 17.0 | 576 | 48.8 | 66.0 | 464 | 39.3 | 17.0 |
| | | E | 1747 | 269 | 15.4 | 7.9 | 1018 | 58.8 | 84.1 | 459 | 26.3 | 7.9 |
| | | S | 1189 | 443 | 37.3 | 17.0 | 527 | 44.3 | 66.0 | 219 | 18.4 | 17.0 |
| | | W | 1208 | 149 | 12.4 | 7.9 | 824 | 68.2 | 84.1 | 234 | 19.4 | 7.9 |
| WOODAR | US 75 | N | 5067 | 709 | 14.0 | 8.4 | 4211 | 83.1 | 83.2 | 147 | 2.9 | 8.4 |
| | | E | 654 | 173 | 26.5 | 39.2 | 410 | 62.7 | 21.5 | 71 | 10.8 | 39.2 |
| | | S | 4804 | 101 | 2.1 | 8.4 | 4386 | 91.3 | 83.2 | 317 | 6.6 | 8.4 |
| | | W | 1471 | 318 | 21.6 | 39.2 | 427 | 29.0 | 21.5 | 727 | 49.4 | 39.2 |
| WOODAR | RUSK | N | 722 | 193 | 26.7 | 25.6 | 314 | 43.5 | 48.8 | 215 | 29.8 | 25.6 |
| | | E | 1193 | 319 | 26.7 | 12.5 | 680 | 57.0 | 75.0 | 194 | 16.3 | 12.5 |
| | | S | 732 | 137 | 18.7 | 25.6 | 460 | 62.9 | 48.8 | 137 | 18.4 | 25.6 |
| | | W | 1789 | 245 | 13.7 | 12.5 | 882 | 49.3 | 75.0 | 652 | 37.0 | 12.5 |
| MAIN | TONE | N | 829 | 30 | 3.6 | 12.4 | 728 | 87.8 | 75.2 | 71 | 8.6 | 12.4 |
| | | E | 1692 | 152 | 9.0 | 22.8 | 179 | 10.6 | 54.5 | 1360 | 80.4 | 22.8 |
| | | S | 2744 | 1432 | 52.2 | 12.4 | 1243 | 45.3 | 75.2 | 69 | 2.5 | 12.4 |
| | | W | 254 | 75 | 29.5 | 22.8 | 203 | 59.9 | 54.5 | 27 | 10.6 | 22.8 |
| MAIN | ARMSTR | N | 2258 | 1057 | 47.2 | 16.0 | 695 | 30.8 | 68.0 | 497 | 22.0 | 16.0 |
| | | E | 1572 | 523 | 33.3 | 6.9 | 949 | 60.4 | 86.3 | 99 | 6.3 | 6.9 |
| | | S | 663 | 88 | 13.3 | 16.0 | 503 | 76.0 | 68.0 | 71 | 10.7 | 16.0 |
| | | W | 1923 | 33 | 1.7 | 6.9 | 983 | 51.1 | 86.0 | 908 | 47.2 | 6.9 |
| BARETT | MAIN | N | 289 | 73 | 25.3 | 39.4 | 118 | 40.8 | 21.2 | 98 | 33.9 | 39.4 |
| | | E | 1594 | 149 | 9.4 | 8.4 | 1256 | 76.9 | 83.3 | 218 | 13.7 | 8.4 |
| | | S | 365 | 118 | 32.3 | 39.4 | 154 | 42.2 | 21.2 | 93 | 25.5 | 39.4 |
| | | W | 1491 | 86 | 5.8 | 8.4 | 1343 | 90.1 | 83.3 | 61 | 4.1 | 8.4 |
| MAIN | MIRICK | N | 1443 | 316 | 21.9 | 18.0 | 812 | 66.1 | 64.0 | 315 | 21.8 | 18.0 |
| | | E | 1467 | 271 | 18.5 | 9.8 | 943 | 64.3 | 80.3 | 252 | 17.3 | 9.8 |
| | | S | 766 | 130 | 17.0 | 18.0 | 506 | 66.0 | 64.0 | 130 | 17.0 | 18.0 |
| | | W | 1558 | 199 | 12.8 | 9.8 | 1030 | 66.1 | 80.3 | 329 | 21.1 | 9.8 |
| FANNIN | MAIN | N | 529 | 167 | 16.7 | 31.7 | 241 | 45.6 | 36.6 | 121 | 22.8 | 31.7 |
| | | E | 1354 | 7 | 0.5 | 11.6 | 1208 | 89.2 | 76.8 | 139 | 10.3 | 11.6 |
| | | S | 484 | 45 | 9.3 | 31.7 | 168 | 34.7 | 36.6 | 271 | 56.0 | 31.7 |
| | | W | 1410 | 8 | 0.6 | 11.6 | 1161 | 82.4 | 76.8 | 240 | 17.0 | 11.6 |
| MAIN | BURNET | N | 395 | 24 | 6.0 | 33.5 | 272 | 68.9 | 33.0 | 99 | 25.1 | 33.5 |
| | | E | 1346 | 34 | 2.5 | 11.1 | 1139 | 84.6 | 77.9 | 173 | 12.9 | 11.1 |
| | | S | 474 | 13 | 2.7 | 33.5 | 297 | 62.7 | 33.0 | 164 | 34.6 | 33.5 |
| | | W | 1286 | 12 | 0.9 | 11.1 | 1056 | 82.1 | 77.9 | 218 | 17.0 | 11.1 |
| MAIN | RUSK | N | 887 | 42 | 4.7 | 18.0 | 678 | 76.4 | 64.0 | 168 | 18.9 | 18.0 |
| | | E | 1214 | 16 | 1.3 | 8.7 | 1003 | 82.6 | 82.5 | 192 | 16.1 | 8.7 |
| | | S | 1047 | 19 | 1.8 | 18.0 | 659 | 62.8 | 64.0 | 371 | 35.4 | 18.0 |
| | | W | 1284 | 41 | 3.2 | 8.7 | 971 | 75.6 | 82.5 | 272 | 21.2 | 8.7 |

| Intersection | | App. Dir. | App. Vol. | Left Turn Count Vol. | Left Turn Count % | Left Turn Theor. % | Thru Movement Count Vol. | Thru Movement Count % | Thru Movement Theor. % | Right Turn Count Vol. | Right Turn Count % | Right Turn Theor. % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lower Volume Intersections (Group B Intersections)** | | | | | | | | | | | | |
| CHESTN | RUSK | N | 527 | 65 | 12.3 | 23.1 | 363 | 68.9 | 53.8 | 99 | 18.8 | 23.1 |
| | | E | 1942 | 487 | 25.1 | 12.4 | 1190 | 61.3 | 75.2 | 264 | 13.6 | 12.4 |
| | | S | 1183 | 256 | 21.6 | 23.1 | 509 | 43.0 | 53.8 | 419 | 35.4 | 23.1 |
| | | W | 1235 | 236 | 19.1 | 12.4 | 722 | 58.5 | 75.2 | 277 | 22.4 | 12.4 |
| CHESTN | BURNET | N | 289 | 35 | 12.1 | 33.8 | 137 | 47.4 | 32.3 | 117 | 40.5 | 33.8 |
| | | E | 1591 | 97 | 6.1 | 10.9 | 1304 | 82.0 | 78.1 | 189 | 11.9 | 10.9 |
| | | S | 583 | 195 | 33.5 | 33.8 | 161 | 27.6 | 32.3 | 227 | 38.9 | 33.8 |
| | | W | 1106 | 117 | 10.6 | 10.9 | 934 | 84.5 | 78.1 | 54 | 4.9 | 10.9 |
| CHESTN | MIRICK | N | 1471 | 76 | 5.2 | 6.4 | 1172 | 79.7 | 87.2 | 224 | 15.1 | 6.4 |
| | | E | 1514 | 254 | 16.8 | 17.0 | 984 | 65.0 | 66.0 | 276 | 18.2 | 17.0 |
| | | S | 1342 | 221 | 16.5 | 6.4 | 989 | 73.7 | 87.2 | 132 | 9.8 | 6.4 |
| | | W | 875 | 110 | 11.4 | 17.0 | 736 | 76.5 | 66.0 | 116 | 12.1 | 17.0 |
| CHESTN | ARMSTR | N | 2332 | 79 | 3.4 | 7.4 | 2001 | 85.8 | 75.6 | 252 | 10.8 | 7.4 |
| | | E | 1203 | 403 | 33.5 | 28.9 | 599 | 49.8 | 42.2 | 201 | 16.7 | 28.9 |
| | | S | 1881 | 139 | 7.4 | 7.4 | 1660 | 88.2 | 75.6 | 83 | 4.4 | 7.4 |
| | | W | 575 | 57 | 9.9 | 28.9 | 412 | 71.7 | 42.2 | 108 | 18.4 | 28.9 |
| CRAWFO | PERRY | N | 790 | 132 | 16.7 | 24.5 | 426 | 53.9 | 51.0 | 232 | 29.4 | 24.5 |
| | | E | 1294 | 229 | 17.7 | 12.5 | 964 | 74.5 | 75.0 | 101 | 7.8 | 12.5 |
| | | S | 610 | 69 | 11.3 | 24.5 | 384 | 63.0 | 51.0 | 157 | 25.7 | 24.5 |
| | | W | 1449 | 94 | 6.4 | 12.5 | 1140 | 78.7 | 75.0 | 214 | 14.8 | 12.5 |
| CRAWFO | ARMSTR | N | 2899 | 371 | 12.8 | 11.7 | 2212 | 76.3 | 76.7 | 316 | 10.9 | 11.7 |
| | | E | 1359 | 289 | 21.3 | 21.0 | 961 | 70.7 | 58.0 | 109 | 8.0 | 21.0 |
| | | S | 2226 | 73 | 3.3 | 11.7 | 2050 | 92.1 | 76.7 | 102 | 4.6 | 11.7 |
| | | W | 1869 | 92 | 4.9 | 21.0 | 1310 | 70.1 | 58.0 | 467 | 25.0 | 21.0 |
| CRAWFO | MIRICK | N | 1520 | 179 | 11.8 | 1.7 | 1140 | 75.0 | 96.6 | 201 | 13.2 | 1.7 |
| | | E | 1124 | 191 | 17.0 | 15.0 | 889 | 79.1 | 70.0 | 44 | 3.9 | 15.0 |
| | | S | 1244 | 58 | 4.7 | 1.7 | 1046 | 84.1 | 96.6 | 139 | 11.2 | 1.7 |
| | | W | 1740 | 177 | 10.2 | 15.0 | 1036 | 75.1 | 70.0 | 256 | 14.7 | 15.0 |
| MORGAN | ARMSTR | N | 3210 | 58 | 1.8 | 5.7 | 2940 | 91.6 | 88.6 | 211 | 6.6 | 5.7 |
| | | E | 510 | 241 | 47.3 | 43.4 | 142 | 27.8 | 13.1 | 127 | 24.9 | 43.4 |
| | | S | 2861 | 60 | 2.1 | 5.7 | 2743 | 95.9 | 88.6 | 58 | 2.0 | 5.7 |
| | | W | 287 | 68 | 23.7 | 43.4 | 170 | 59.2 | 13.1 | 49 | 17.1 | 43.4 |
| HULL | ARMSTR | N | 3203 | 96 | 3.0 | 9.7 | 2876 | 89.8 | 80.5 | 231 | 7.2 | 9.7 |
| | | E | 857 | 310 | 32.7 | 36.7 | 452 | 48.0 | 26.5 | 180 | 19.1 | 36.5 |
| | | S | 3074 | 175 | 5.7 | 9.7 | 2736 | 89.0 | 80.7 | 163 | 5.3 | 9.7 |
| | | W | 809 | 189 | 23.4 | 36.7 | 473 | 58.5 | 26.5 | 146 | 18.1 | 36.5 |
| HULL | MIRICK | N | 1564 | 114 | 7.3 | 12.4 | 1352 | 86.5 | 75.2 | 97 | 6.2 | 12.4 |
| | | E | 885 | 85 | 8.7 | 22.5 | 549 | 56.4 | 55.0 | 340 | 34.9 | 22.5 |
| | | S | 1680 | 280 | 16.7 | 12.4 | 1202 | 71.6 | 75.2 | 196 | 11.7 | 12.4 |
| | | W | 899 | 205 | 22.8 | 22.5 | 565 | 62.9 | 55.0 | 129 | 14.3 | 22.5 |
| TEXAS | MIRICK | N | 1427 | 21 | 1.5 | 5.5 | 1366 | 95.7 | 89.0 | 40 | 2.8 | 5.5 |
| | | E | 194 | 57 | 29.4 | 43.8 | 74 | 38.1 | 12.5 | 63 | 32.5 | 43.8 |
| | | S | 1358 | 54 | 4.0 | 5.5 | 1269 | 93.5 | 89.0 | 34 | 2.5 | 5.5 |
| | | W | 153 | 47 | 30.7 | 43.8 | 80 | 52.3 | 12.5 | 26 | 17.0 | 43.8 |
| MURRAT | MIRICK | N | 1240 | 25 | 2.0 | 8.2 | 1135 | 91.5 | 83.6 | 81 | 6.5 | 8.2 |
| | | E | 217 | 57 | 26.3 | 39.6 | 98 | 45.1 | 20.7 | 62 | 28.6 | 39.6 |
| | | S | 1292 | 43 | 3.3 | 8.2 | 1189 | 92.0 | 83.6 | 61 | 4.7 | 8.2 |
| | | W | 308 | 100 | 32.5 | 39.6 | 135 | 43.8 | 20.7 | 73 | 23.7 | 39.6 |
| BULLOC | US 75A | N | 2732 | 71 | 2.6 | 11.6 | 2472 | 90.5 | 71.7 | 190 | 6.9 | 11.6 |
| | | E | 986 | 164 | 16.7 | 31.5 | 442 | 44.9 | 37.0 | 381 | 28.4 | 31.5 |
| | | S | 3295 | 418 | 12.7 | 11.6 | 2346 | 71.2 | 71.7 | 530 | 16.1 | 11.6 |
| | | W | 1239 | 589 | 47.5 | 31.5 | 541 | 43.7 | 37.0 | 109 | 8.8 | 31.5 |
| COFFIN | US 75A | N | 3321 | 3 | 0.1 | 5.6 | 2292 | 90.1 | 88.8 | 325 | 9.8 | 5.6 |
| | | E | 810 | 375 | 46.3 | 43.6 | 4 | 0.5 | 12.8 | 431 | 53.2 | 43.6 |
| | | S | 3056 | 364 | 11.9 | 5.6 | 2686 | 87.9 | 88.8 | 6 | 0.2 | 5.6 |
| | | W | 11 | 5 | 45.5 | 43.6 | 2 | 18.2 | 12.8 | 4 | 36.3 | 43.6 |
| US 75 | COFFIN | N | 4677 | 159 | 3.4 | 4.6 | 4438 | 94.9 | 90.9 | 80 | 1.7 | 4.6 |
| | | E | 200 | 35 | 17.5 | 44.9 | 107 | 53.5 | 10.2 | 59 | 29.0 | 44.9 |
| | | S | 5339 | 69 | 1.3 | 4.6 | 4618 | 86.5 | 90.9 | 651 | 12.2 | 4.6 |
| | | W | 819 | 564 | 68.9 | 44.9 | 140 | 17.1 | 10.2 | 115 | 14.0 | 44.9 |

| Intersection | | App. Dir. | App. Vol. | Left Turn | | | Thru Movement | | | Right Turn | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Count | | Theor. | Count | | Theor. | Count | | Theor. |
| | | | | Vol. | % | % | Vol. | % | % | Vol. | % | % |
| **Lower Volume Intersections (Group B Intersections)** | | | | | | | | | | | | |
| FM 691 | FM 131 | N | 891 | 514 | 57.5 | 34.9 | 30 | 3.4 | 30.1 | 348 | 39.1 | 34.9 |
| | | E | 1429 | 304 | 21.3 | 10.5 | 1110 | 77.7 | 79.0 | 14 | 1.0 | 10.5 |
| | | S | 66 | 13 | 19.7 | 34.9 | 28 | 42.4 | 30.1 | 25 | 37.9 | 34.9 |
| | | W | 1748 | 23 | 1.3 | 10.5 | 1161 | 66.4 | 79.0 | 565 | 32.3 | 10.5 |
| FM 691 | FM 141 | N | 1967 | 530 | 26.8 | 7.0 | 808 | 40.9 | 86.0 | 638 | 32.3 | 7.0 |
| | | E | 1264 | 446 | 35.3 | 17.0 | 634 | 50.2 | 66.0 | 183 | 14.5 | 17.0 |
| | | S | 1256 | 275 | 21.9 | 7.0 | 861 | 68.6 | 86.0 | 245 | 19.5 | 7.0 |
| | | W | 1426 | 163 | 11.4 | 17.0 | 736 | 51.6 | 66.0 | 528 | 37.0 | 17.0 |
| TAYLOR | LOY LA | N | 1475 | 316 | 21.4 | 16.0 | 953 | 64.6 | 68.0 | 207 | 14.0 | 16.0 |
| | | E | 1348 | 109 | 8.1 | 3.4 | 1091 | 80.9 | 93.3 | 148 | 11.0 | 3.4 |
| | | S | 1990 | 143 | 7.2 | 16.0 | 973 | 48.9 | 68.0 | 874 | 43.9 | 16.0 |
| | | W | 2387 | 883 | 37.0 | 3.4 | 1155 | 48.4 | 93.3 | 348 | 14.6 | 3.4 |
| TAYLOR | FM 131 | N | 2470 | 183 | 7.4 | 10.2 | 1647 | 66.7 | 79.6 | 639 | 25.9 | 10.2 |
| | | E | 2081 | 350 | 16.8 | 19.0 | 894 | 43.0 | 62.0 | 837 | 40.2 | 19.2 |
| | | S | 2530 | 744 | 29.4 | 10.2 | 1685 | 66.6 | 79.6 | 101 | 4.0 | 10.2 |
| | | W | 1502 | 120 | 8.0 | 19.0 | 1054 | 70.2 | 62.0 | 327 | 21.8 | 10.2 |
| WASHIN | FM 141 | N | 2053 | 35 | 1.7 | 10.2 | 1864 | 90.8 | 79.6 | 154 | 7.5 | 10.2 |
| | | E | 967 | 165 | 17.1 | 35.8 | 87 | 9.0 | 28.5 | 715 | 73.9 | 35.8 |
| | | S | 2104 | 776 | 36.9 | 10.2 | 1290 | 61.3 | 79.6 | 38 | 1.8 | 10.2 |
| | | W | 217 | 52 | 24.0 | 35.8 | 154 | 71.0 | 28.5 | 11 | 5.0 | 35.8 |
| LAMBER | FM 141 | N | 2651 | 172 | 6.5 | 6.7 | 2142 | 80.8 | 86.6 | 337 | 12.7 | 6.7 |
| | | E | 479 | 1155 | 58.5 | 42.0 | 170 | 8.6 | 16.0 | 649 | 32.9 | 42.0 |
| | | S | 1974 | 146 | 7.4 | 6.7 | 1770 | 89.7 | 86.6 | 57 | 2.9 | 6.7 |
| | | W | 261 | 80 | 30.7 | 42.0 | 38 | 14.6 | 16.0 | 143 | 54.7 | 42.0 |
| FM 141 | SAM RA | N | 1473 | 551 | 37.4 | 27.9 | 144 | 9.8 | 44.3 | 778 | 52.8 | 27.9 |
| | | E | 1875 | 165 | 8.8 | 12.3 | 818 | 43.6 | 75.3 | 893 | 47.6 | 12.3 |
| | | S | 369 | 208 | 56.4 | 27.9 | 94 | 25.5 | 44.3 | 67 | 18.1 | 27.9 |
| | | W | 2286 | 919 | 40.2 | 12.3 | 1118 | 48.9 | 75.3 | 249 | 10.9 | 12.3 |
| MULBER | WALNUT | N | 1283 | 210 | 16.4 | 16.0 | 851 | 66.3 | 68.0 | 222 | 17.3 | 16.0 |
| | | E | 2151 | 88 | 4.1 | 2.5 | 1150 | 53.5 | 95.1 | 912 | 42.4 | 2.5 |
| | | S | 1442 | 727 | 50.4 | 16.0 | 528 | 36.6 | 68.0 | 187 | 13.0 | 16.0 |
| | | W | 724 | 99 | 13.7 | 2.5 | 566 | 78.2 | 95.1 | 59 | 8.1 | 2.5 |
| CROCKE | PECON | N | 2153 | 161 | 7.5 | 11.5 | 1601 | 74.4 | 76.9 | 390 | 18.1 | 11.5 |
| | | E | 664 | 159 | 24.0 | 21.0 | 301 | 45.3 | 58.0 | 204 | 30.7 | 21.0 |
| | | S | 1108 | 204 | 18.5 | 11.5 | 806 | 72.7 | 76.9 | 97 | 8.8 | 11.5 |
| | | W | 1416 | 340 | 24.0 | 21.0 | 817 | 57.7 | 58.0 | 259 | 18.3 | 21.0 |
| WALL | CROCKE | N | 1864 | 65 | 3.5 | 11.1 | 1634 | 87.7 | 77.7 | 164 | 8.8 | 11.1 |
| | | E | 652 | 40 | 6.1 | 33.3 | 127 | 19.5 | 33.4 | 485 | 74.4 | 33.3 |
| | | S | 1122 | 64 | 5.7 | 11.1 | 942 | 84.0 | 77.7 | 116 | 10.3 | 11.1 |
| | | W | 306 | 121 | 36.0 | 33.3 | 91 | 27.1 | 33.4 | 124 | 36.9 | 33.3 |
| COLLEG | TRAVIS | N | 1194 | 33 | 2.8 | 12.5 | 1118 | 93.6 | 65.5 | 44 | 3.6 | 12.5 |
| | | E | 1439 | 86 | 6.0 | 26.1 | 121 | 8.4 | 47.7 | 1232 | 85.6 | 26.1 |
| | | S | 3577 | 269 | 7.5 | 12.5 | 2342 | 65.5 | 65.5 | 966 | 27.0 | 12.5 |
| | | W | 837 | 513 | 61.3 | 26.1 | 222 | 26.5 | 47.7 | 102 | 12.2 | 26.1 |
| RROCKE | TRAVIS | N | 898 | 22 | 2.4 | 11.4 | 782 | 87.1 | 77.1 | 94 | 10.5 | 11.4 |
| | | E | 859 | 317 | 36.9 | 32.3 | 271 | 31.6 | 35.4 | 271 | 31.5 | 32.3 |
| | | S | 2513 | 121 | 4.8 | 11.4 | 2347 | 93.4 | 77.1 | 45 | 1.8 | 11.4 |
| | | W | 348 | 67 | 19.3 | 32.3 | 244 | 70.1 | 35.4 | 37 | 10.6 | 32.3 |
| HILL | TRAVIS | N | 3341 | 0 | 0.0 | 7.7 | 3328 | 99.6 | 84.7 | 13 | 0.4 | 7.7 |
| | | E | 41 | 7 | 17.1 | 40.5 | 0 | 0.0 | 18.9 | 34 | 82.9 | 40.5 |
| | | S | 3937 | 12 | 0.3 | 7.7 | 3925 | 99.7 | 84.7 | 0 | 0.0 | 7.7 |
| | | W | 1132 | 1027 | 90.7 | 40.5 | 16 | 1.4 | 18.9 | 89 | 7.9 | 40.5 |