TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.: FHWA/TX-90/1153-3

2. Government Accession No.:

3. Recipient's Catalog No.: August 1990

4. Title and Subtitle: A COMPARISON OF TRAFFIC ASSIGNMENT TECHNIQUES

5. Report Date:

6. Performing Organization Code:

7. Author's: Duk M. Chang and George B. Dresser

8. Performing Organization Report No.: Research Report 1153-3

9. Performing Organization Name and Address:
Texas Transportation Institute
The Texas A&M University System
College Station, TX 77843

10. Work Unit No.:

11. Contract or Grant No.: 2-10-89-1153

12. Sponsoring Agency Name and Address:
State Department of Highways and Public Transportation
Transportation Planning Division
P. O. Box 5051, Austin, Texas 78763

13. Type of Report and Period Covered: Interim - September 1989 - August 1990

14. Sponsoring Agency Code:

15. Supplementary Notes:
Research performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Research Study Title: Improving the Efficiency and Responsiveness of the Traffic Assignment Process.

16. Abstract

This report compares and evaluates the traffic assignment results from five assignment techniques: all-or-nothing, stochastic multipath, iterative, incremental, and equilibrium. The results of the assigned volumes from the five techniques are compared to ground counts. Various statistical measures are used to evaluate the results. Five different assignments of the existing Tyler, Texas, network were compared to ground counts to determine if there were differences among the results. Measures of how well the assignment reproduces traffic counts were divided into two groups: macro-level measurements (screenlines, cutlines, and VMT) which are network-wide analyses and micro-level measures which are link-by-link comparisons.

No significant difference was found among the five assignment techniques when using the macro-level measures. The values for the incremental assignment had the best results compared to ground counts when using micro-level measures.

Some of the statistical measures were affected by the introduction of capacity restraint. Otherwise, it was concluded that the incremental and the equilibrium assignments represented a slight improvement from the all-or-nothing and the stochastic multipath assignments. However, the difference in results was not significant enough when using capacity restraint to warrant the extra cost such as link capacity data and computer run time involved in the capacity-restraint assignments. This implies that much of the precision in the assignment procedure using the different techniques may be sacrificed and still produce acceptable assignment results.

17. Key Words: Traffic Assignment, All-or-Nothing, Stochastic Multipath, Capacity-Restraint, Equilibrium

18. Distribution Statement: No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	62	

Form DOT F 1700.7 (8-69)

A COMPARISON OF TRAFFIC ASSIGNMENT TECHNIQUES

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Research Report Number 1153-3
Research Study Number 2-10-89-1153

Sponsored by
Texas State Department of Highways and Public Transportation

In cooperation with
U.S. Department of Transportation
Federal Highway Administration

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

August 1990

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
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

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

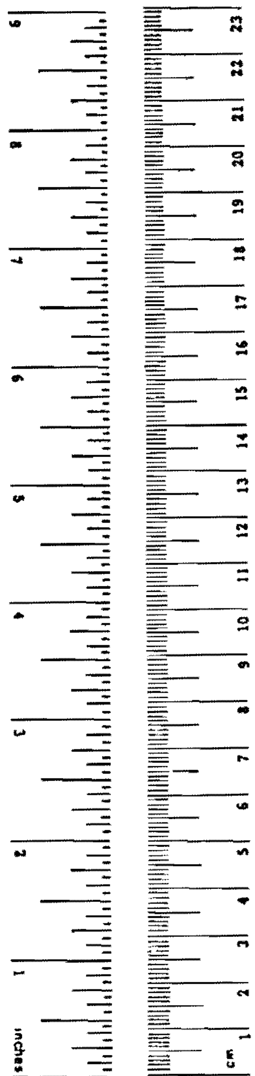
VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
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

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
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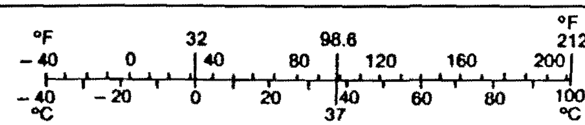

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

This report compares and evaluates the traffic assignment results from five assignment techniques: all-or-nothing, stochastic multipath, iterative, incremental, and equilibrium. The results of the assigned volumes from the different assignment techniques are compared to ground counts. Various statistical measures are used for evaluation of assignment results.

Five different assignments of the existing Tyler network were compared to ground counts to determine if there were differences among the results. Measures of how well the assignment reproduces traffic counts were divided into two groups: macro-level measurements (screenlines, cutlines, and vehicle-miles of travel) which are network-wide analyses; and micro-level measures (absolute link volumes, percent link volumes, link volumes by counted volume groups, mean, standard deviation, and percent root-mean-square error differences) which are link-by-link comparisons.

It was found that there is no significant difference among the five assignment techniques when using the macro-level measures. All five assignment techniques gave good results (within acceptable ranges) when compared to the ground counts based on the three macro-level measures. The values for the incremental assignment had the best results compared to the ground counts when using the micro-level measures.

Some of the statistical measures were affected by the introduction of capacity restraint. Otherwise, it was concluded that the incremental and the equilibrium assignments represented a slight improvement from the all-or-nothing and the stochastic multipath assignments. However, the difference in results was not significant enough when using capacity restraint to warrant the extra cost such as link capacity data and computer run time involved in the capacity-restraint assignments. This implies that much of the precision in the assignment procedure using the different techniques may be sacrificed and still produce acceptable assignment results.

DISCLAIMER

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INTRODUCTION

The focus of this report is to study the sensitivity of the traffic assignment generated from different assignment techniques. The results of the assigned volumes from the different assignment techniques are compared to the ground counts. Various statistical measures are used for evaluation of assignment results.

There are four basic phases in the traditional travel demand forecasting process. Trip generation projects the number of trips to and from geographical areas (zones) based on the various urban activities. Trip distribution determines the trips between all zone pairs thereby linking productions and attractions. Mode choice is the process of projecting how many travelers will use each of the available or proposed transportation modes. Finally, traffic assignment is a process used for estimating traffic volumes on a coded transportation system using the travel-demand information developed in the previous modeling steps. Traffic assignment is not only the last phase of the modeling process used in urban transportation planning for assigning the trips to specific routes and establishing volumes on links, but also the most widely used portion of the total process. Uses of the traffic assignment results include:

1. Evaluation of land-use and transportation system alternatives;
2. Establishment of short-range priority programs for transportation facility development;
3. Analysis of alternative locations for facilities;
4. Provision of necessary input and feedback for other planning tools; and
5. Estimation of design traffic volumes.

The problem of traffic assignment in the sequential urban travel forecasting process is how to assign (or allocate) a specified number of vehicles (or persons) to the paths taken from one zone centroid to another. Inputs to the traditional traffic assignment process include:

1. A trip table which represents the number of trips between each zone pair, and
2. A coded network which is an abstract representation of a transportation system.

The output of the traffic assignment process basically consists of loads (volumes) on each link of the transportation network. These may be 24-hour vehicular highway traffic volumes, peak period transit volumes, or the number of transit riders.

Assignment techniques rely on the determination of paths through a network based upon link impedances such as time, distance, cost of travel, or a combination of these. Zonal interchange values described by an origin and destination are then accumulated on the network links comprising the paths calculated between the pairs of zone centroids. The accumulation of all origin-destination interchange volumes on each network link is the load on that link. Various assignment techniques are available to determine the link loadings; these are all-or-nothing, stochastic multipath, iterative or incremental capacity restraint, and equilibrium assignment techniques. The last, equilibrium, is a special case of capacity-restraint assignment by which total travel impedance is minimized. The all-or-nothing assignment technique assigns all trips to the shortest path. The stochastic multipath technique assigns trips to all "efficient" paths according to their probabilities of being used based on the difference in impedance and a control value of probability function.

Capacity restraint uses the results of the previous assignment to adjust the link impedance based on the assigned volume-to-capacity (V/C) ratio for the link. That is, the process attempts to adjust the link impedance so as to bring the assigned link volume into balance with capacity of the link. Equilibrium assignment algorithms utilizing mathematical programming techniques have been shown to give more realistic representations of traffic volumes than the all-or-nothing assignment. In general, equilibrium assignments produce better results than other capacity-restraint assignments because the equilibrium technique assumes that total travel impedance on the network is minimized. The research hypothesis is that the equilibrium traffic assignment technique provides better results than the all-or-nothing, the stochastic multipath, the iterative, or the incremental techniques when compared to ground counts.

METHODOLOGY

The assignment of existing trips to the existing network is compared to ground counts to determine if the modeling process produces realistic results. Measures of how well the assignment reproduces traffic counts can be divided into two groups: macro-level measures which are network-wide analyses; and micro-level measures which are link-by-link comparisons. Differences between the assignment results and ground counts may be due to inaccuracies in trip generation, in network representation, in link impedances, in ground counts, or any combination of these.

Evaluation procedures for traffic assignment results are described in Traffic Assignment: Methods, Applications, Products (1). Traffic assignment techniques must be evaluated to determine their ability to reflect reality. The most critical check of assignment results would be comparisons of assigned volumes with ground counts on individual link segments. Sources of error in both assigned volumes and ground counts must be known as accurately as possible. Also, the document identified five statistical measures to compare traffic assignment results with ground counts:

1. A comparison of total counted volume to total assigned volume across some aggregation such as total study area, subarea and/or facility types, or screenlines, gridlines and cutlines.
2. A comparison of total vehicle-miles of travel (VMT) from ground counts to VMT from the assignment results.
3. The development of the total weighted error. The total weighted error is calculated from percent standard deviation multiplied by the percent of total in each volume group.
4. The calculation of root-mean-square (RMS) errors comparing ground counts and assigned volumes by link within the stratification chosen for comparison.
5. A graphic comparison of ground counts versus assigned volumes.

Assignment accuracy was evaluated using both macro-level and micro-level measures in this research. Macro-level measurements of assignment accuracy are those measures that analyze the entire network or specific portions of the network. These measures were:

1. Screenlines compare the total assigned volumes to total counted volumes of all links intersecting an imaginary line dividing the study area into two parts.
2. Cutlines are similar to screenlines but intersect links of a travel corridor rather than the entire study area. This measure is somewhat more precise than screenlines in that it evaluates the assignment's ability to replicate travel on a more narrowly-defined travel corridor.
3. VMT are calculated by multiplying the length of a link by its respective volume. The volumes are accumulated along selected links as opposed to volumes accumulated on a specific link which is intersected by a screenline or by a cutline. The degree to which the assigned VMT matches the counted VMT is measured by the ratio (in percent) of the assigned VMT to the counted VMT.

Assignment accuracy was evaluated using micro-level measures. Micro-level measures of assignment accuracy are those measures that analyze the differences between counted and assigned volumes on a link-by-link basis. The common statistical measures and non-parametric statistical test were employed in the evaluation of link difference. These measures included the following:

1. Distribution of link differences by error ranges: The differences between assigned and counted link volumes were tabulated for each link for absolute error ranges and percent error ranges. The accumulated number of links in each range was converted to a percentage of the total links. The distribution of differences by error ranges gives a perspective of the dispersion of error.
2. Statistical measures of link differences: Five common statistical measures were employed in the evaluation of link differences. The mean difference is a measure of the central tendency of the distribution. The standard deviation is a measure of the dispersion of the differences relative to a mean difference. The root-mean-square error is a measure of the dispersion of the differences relative to a zero difference. Therefore, the root-mean-square error should be a better measurement than the standard deviation. Percent standard deviation or percent root-mean-square error measure the relationship between

the standard deviation or the root-mean-square error and the average counted volume. Since the counted volume remained the same for a given network, the average counted volume was a constant and the percent standard deviation was simply the standard deviation divided by a constant. Also, the percent root-mean-square error was the root-mean-square error divided by a constant. The following relationships were used for calculation:

Mean Difference (MD) $= \Sigma (A_i - C_i) / N$

Standard Deviation (SD) $= \sqrt{(\Sigma (A_i - C_i)^2/(N-1)) - (\Sigma (A_i - C_i)/N)^2}$

Root-Mean-Square (RMS) $= \sqrt{(\Sigma (A_i - C_i)^2 / (N-1))}$

Percent SD (PSD) $= 100 \times (SD / (\Sigma C_i/N))$

Percent RMS (PRMS) $= 100 \times (RMS / (\Sigma C_i/N))$

where: A_i = assigned volume for link i

C_i = counted volume for link i

N = total number of links

3. Statistical test of link differences: The Chi-Square goodness-of-fit test was employed to determine if any of the differences between assigned and counted volumes were statistically significant. Then, the test result was used to compare different traffic assignment techniques.

The Chi-Square (X^2) goodness-of-fit test was performed on both the results of the assignments and the ground counts using volume group intervals; the number of links (assigned and counted) in each volume group were compared. The hypothesis tested was that assigned link volumes are distributed the same as counted link volumes. The test concerning k-specified cell volume groups was as follows:

H_o: Assigned volumes are distributed the same as ground counts.

H_a: Assigned volumes are distributed independent of ground counts.

Test Statistic: $X^2 = \sum_{i=1}^{k} [(O_i - E_i)^2 / E_i]$

where:

O_i = observed cell counts in volume group "i"

E_i = expected cell counts in volume group "i"

k = total number of volume groups

Reject Region: Reject H_o if the calculated X^2 exceeds the tabulated critical value for $\alpha = 0.10$ and $df = k-1$.

The number of links was tabulated in each of the volume groups for each of the five sets of traffic assignment results. The expected values (E_i) were the number of links in each ground count volume group, and the observed cell values (O_i) were the number of links from the traffic assignments. The Chi-Square test requires that the expected cell counts not be too small. Siegel (2) recommends that fewer than 20 percent of the cells have an expected frequency of less than five and that no cell have an expected frequency of less than one when the degrees of freedom are larger than one. If these requirements are not met, cells with counts of less than five are combined with an adjacent cell(s).

STUDY AREA

The existing 1985 network for Tyler, Texas, shown in Figure 1 was selected for this evaluation bed. The Tyler network consisted of 220 internal zones, 32 external stations, 676 nodes, and 1750 directional (one-way) links (including the links to external stations but excluding centroid connectors). The assignment model and its input assignment parameters were checked in a variety of ways. Travel time was used as the measure of travel impedance. Turn penalties and turn prohibitors were not used. Trees were built and plotted for six zones. Visual evaluation of the six trees was satisfactory. The Network Editing and Displaying System (NEDS) microcomputer software was used to check the paths between an additional 40 selected zone pairs. All of the selected zone pairs were examined and were found to have logical-shortest paths. The checks indicated that the paths were reasonable without the use of turn penalties and turn prohibitors.

USE OF TRAFFIC ASSIGNMENT TECHNIQUES

ALL-OR-NOTHING ASSIGNMENT

An all-or-nothing assignment is the common, traditional traffic assignment methodology which assigns all trips to the shortest path. This is a free-flow assignment with no consideration given to the link capacities. Consequently, the network impedance from which minimum paths are built is the only required parameter to specify for this assignment. If more than one shortest path exists, a method known as a "tie breaker" is used so that only one path will be selected. TRANPLAN uses a first-link-selected tie breaker, and the paths are in hundredths of a minute.

STOCHASTIC MULTIPATH ASSIGNMENT

A stochastic multipath method known as a Dial's algorithm assigns trips to all "efficient" paths according to the probabilities of particular paths being used based on the differences in impedances. Trips are assigned to all "reasonable" paths between each origin and destination centroid with each path receiving a fraction of interzonal trips which is proportional to

EXP (-THETA x DELTA) = Probability of a path receiving trips.

where:	THETA	=	user-specified diversion parameter
	DELTA	=	difference between the minimum path impedance and the alternate path impedance.

The diversion parameter is used to determine likely paths. If THETA is zero, all efficient paths are considered equal and receive the same probability of the trips; if THETA is large (e.g., 10) only the minimum path receives the trips. A diversion parameter of 0.2 was used in this research. Consequently, if DELTA has a difference of one minute, there is an 81.9 percent probability that the alternate path will receive trips; if DELTA is five minutes, a 36.8 percent probability will be used for the path.

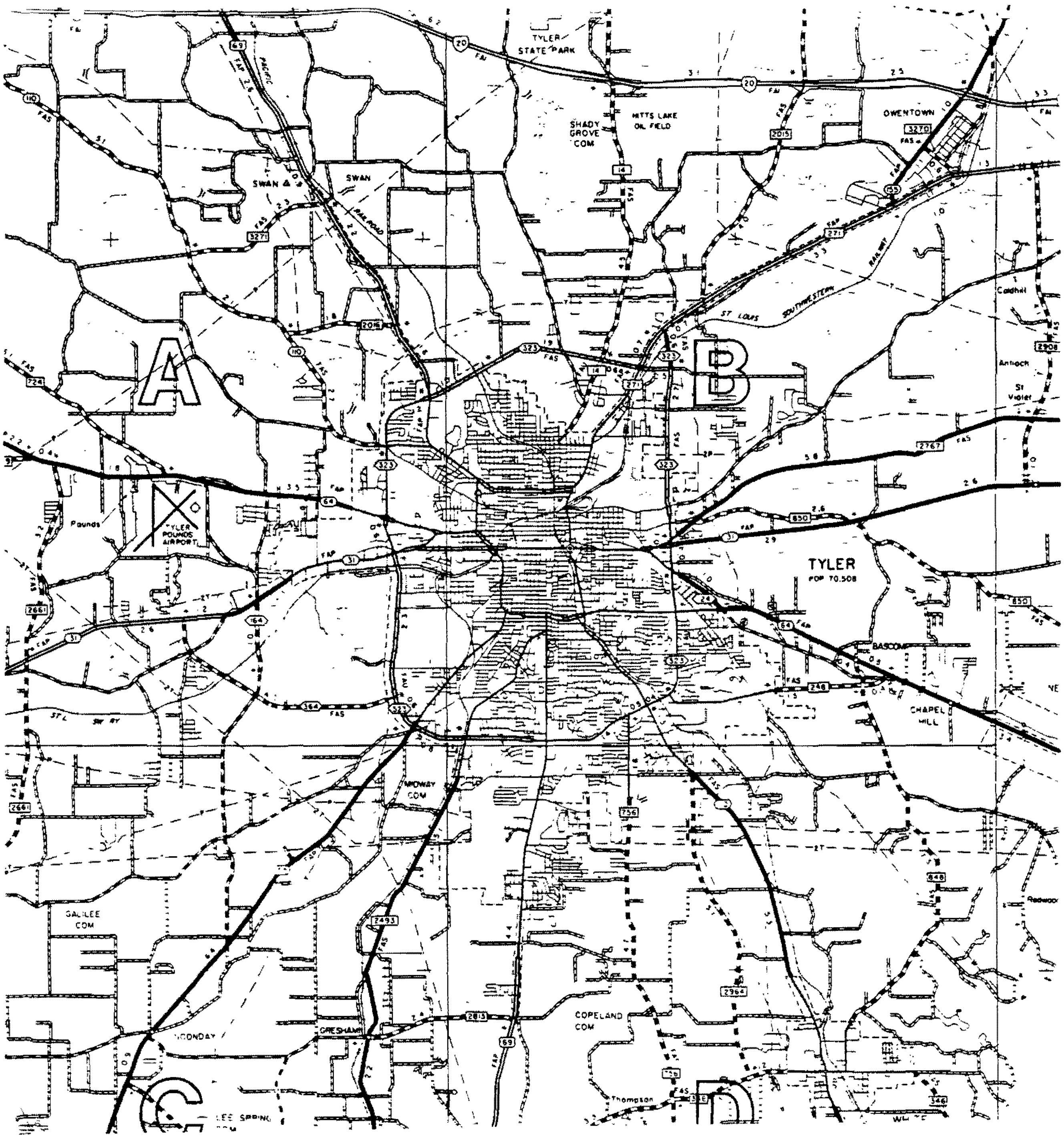


FIGURE 1. Existing Network of Study Area in Tyler.

ITERATIVE CAPACITY-RESTRAINT ASSIGNMENT

A capacity-restraint assignment uses the results of the previous assignment to adjust the link impedance based on the assigned V/C ratio for the link. That is, the process attempts to adjust the link impedance so as to bring the assigned link volume into balance with capacity of the link. There are two techniques to perform capacity-restraint assignment: the iterative and the incremental. Both capacity-restraint techniques are based on the finding that as traffic flow increases, the speed of traffic decreases.

The formula used in the capacity-restraint assignment is the standard BPR capacity-restraint formula or other equation based on the V/C ratio for each link. In TRANPLAN, the travel impedance is adjusted link by link according to the user-specified V/C time adjustment curve data or the following capacity-restraint formula:

$$T_n = T_{n-1} \times [1.0 + 0.15(V/C)^4] \times 0.87$$

where:
- n = current restraint iteration
- T_n = travel impedance on loaded link
- T_{n-1} = travel impedance of the previous iteration
- V = assigned volume
- C = capacity specified in link data

TTI research report 1110-2 (3) recommended that the user-specified V/C time adjustment curve data be used in TRANPLAN. The recommended user curve data is the final formulation of the impedance adjustment function in the Texas Package. The bounding condition, $\text{Max}(I_{(n+1)}) \leq (n+1)I_1$, is placed on the impedance adjustment function in the Texas Large Network Assignment Models in running Assign Self-Balancing. However, this limit cannot be simulated in each iteration of TRANPLAN. Instead of the bounding condition, the minimum limit of 0.167 (for base time/adjusted time) might be used in the V/C ratio of 2.4 or higher. Finally, it was recommended that the following curve data should be specified using the data specifications in a TRANPLAN control file:

```
$DATA
      ASSIGNMENT GROUP = 0-9, XYDATA = (0.0,1.087) (0.5,1.076) (1.0, .935)
                              (1.5,0.595) (2.0,0.301) (2.4,0.167) (4.0,0.167)
$END TP FUNCTION
```

The iterative technique consists of a successive number of minimum path selections, loadings of 100 percent trip interchange volumes, and each link impedance adjustment to obtain a balanced load on a network. Therefore, the first iteration of a capacity-restraint assignment is the same as an all-or-nothing assignment. The number of iterations is a user input value. It is desirable to apply capacity restraint at least three times to take advantage of the diversion effect of the process.

INCREMENTAL CAPACITY-RESTRAINT ASSIGNMENT

For each iteration of the incremental technique, a given percentage of selected interzonal highway trips is loaded on the minimum paths. In defining the iteration weights, later assignments (iterations) should be weighted more heavily than earlier ones. Additionally, in an effort to dampen oscillations in the assignments to parallel facilities on consecutive iterations, successive pairs of all-or-nothing assignments should receive equal weights. As a result of these considerations, iteration weights of 15 percent, 15 percent, 20 percent, 20 percent, and 30 percent were recommended in the incremental assignment in TRANPLAN.

Traffic Assignment: Methods, Applications, Products (1) defined two general types of incremental assignments: minimum paths between each pair of zones are calculated once and trips loaded once, and several route-building steps and loadings must occur during the capacity-restraint application. The disadvantages of the first type of incremental assignment include the variability in results depending upon the order of zone selection and the loss of a "diversion" effect between pairs of zones.

The second type of incremental loading, developed by Control Data Corporation, overcomes the above disadvantages but at the cost of requiring several tree building and loading steps. In this method, minimum path trees are built using the travel impedance provided for the original network. Instead of randomly selected origin zones used in the first type of incremental loading, each network link is loaded with the first increment of all zone-to-zone movements passing through it. This increment is some percent of total trips. The second type of incremental loading is used in TRANPLAN with an option of a user-specified percentage of the increment. There are various options and parameters for the TRANPLAN capacity-restraint assignment procedures in both the iterative and the incremental assignments:

1. The DAMPING option specifies that the impedance is adjusted only by the user-specified factor. This option was not used in either assignment.
2. The BASE NETWORK option specifies that the adjusted network for any iteration is based upon the initial link impedance. This option was used in both the iterative and incremental assignments.
3. The five iterations were used in the iterative assignment.
4. The ADJUST 100 option specifies that the loaded volumes were expanded to 100 percent before the V/C ratio was calculated for link impedance adjustment. This option was used in the incremental assignment.
5. The LOAD PERCENTAGES parameter of 15, 15, 20, 20, and 30 percent of the total trip volume was applied in the first through fifth iterations in the incremental assignment.
6. The recommended user-specified V/C time adjustment curve data was used in both the iterative and the incremental assignments.

EQUILIBRIUM ASSIGNMENT

Equilibrium assignment algorithms utilizing mathematical programming techniques have been shown to give more behaviorally realistic representations of the traffic patterns than the all-or-nothing or capacity-restraint method (4,5). An equilibrium assignment is constrained to each link travel impedance, link capacity, and, additionally, the total travel impedance of the network. The procedure produces an assignment in which total travel impedance on the network is minimized. The results of the first iteration of an equilibrium assignment are the same as an all-or-nothing assignment.

The theory behind this process is commonly referred to as the Wardrop condition:

"find the assignment of vehicles to links such that no traveler can reduce his or her travel time from origin to destination by switching to another path." A traveler first selects his path along the route he believes to be the minimum time. But other travelers also use parts of his path and the time increases. He then shifts to a different path (as do other travelers). Then that path gets congested, and he selects another path (as others may do, also). Eventually, he cannot find a faster path, and the travel time on the final path is about the same as it would be on the congested original path. At that point, the system is close to equilibrium.

In the report, Equilibrium Trip Assignment: Advantages and Implications for Practice, by Eash, Janson, and Boyce (4), the user-equilibrium problem is stated mathematically and conceptually in simplest notations (forms). If the trip matrix (T_{ij}) is given, the equilibrium assignment of trips to links may be found by solving the following nonlinear programming problem:

Minimize: $\sum_a \int_0^{V_a} S_a(x)dx$

Subject to: $V_a = \sum_i \sum_j \sum_r s^{a\,r}_{i\,j} X^r_{ij}$

$\sum_r X^r_{ij} = T_{ij}$ and $X^r_{ij} \geq 0$

where: V_a = number of vehicles on link "a" of the network

$S_a(V_a)$ = generalized travel time on link "a", which increases with flow "V" (a typical congestion function is the BPR capacity-restraint formula)

$s^{a\,r}_{i\,j}$ = 1 if link "a" belongs to path "r" from zone "i" to zone "j", 0 otherwise

Xr_{ij} = number of vehicles of zone "i" to zone "j" on path "r"

For all links "a" in the networks; "i" = 1,...N; "j" = 1,...N; and N = number of zones.

The link flows for which the objective function of the equilibrium assignment achieves its minimum value are those that satisfy the equilibrium conditions stated by Wardrop. Hence, the solution that minimizes the sum of the integrals of the congestion functions for all of the links is the equilibrium solution. The equilibrium-assignment algorithm, given a network with congestion functions for each link, a trip matrix to be assigned, and a current solution for the link loadings (V_a), is summarized based on the following five steps:

1. Compute the travel time on each link $S_a(V_a)$ that corresponds to the flow V_a in the current solution.
2. Trace minimum path trees from each origin to all destinations using the travel times from Step 1.
3. Assign all trips from each origin to each destination for the minimum path (all-or-nothing assignment). Call this link loading W_a.
4. Combine the current solution (V_a) and the new assignment (W_a) to obtain a new current solution (V_a') by using a value LAMBDA selected so as to minimize the following objective function:

$$\text{Minimize: } \sum_a \int_0^{V'_a} S_a(x)dx$$

$$\text{where: } \quad V_a' = (1 - \text{LAMBDA})V_a + (\text{LAMBDA})W_a$$

5. If the solution has converged sufficiently here, stop. Go on to the next iteration; otherwise, return to Step 1.

There are various options and parameters for the TRANPLAN equilibrium assignment procedures. The following options and parameters were used in this procedure:

1. The EQUILIBRIUM ITERATIONS parameter of 5 was used.
2. The UROAD FACTOR parameter of 1.0 was used. Therefore, the coded link capacities were used in all iterations.
3. Initially, the major closing criterion (EPS parameter) of 0.1 was used. When

EPS of 0.1 was used, the assignments stopped after the third iteration. Therefore, the major closing criterion was changed to 0.01 in order to produce better results.

MACRO-LEVEL ANALYSES

Three measures of assignment accuracy at the macro-level (screenlines, cutlines, and vehicle-miles traveled) were utilized in evaluating the assignment results from the five techniques. Appendix A shows the output files for the macro-level analysis using TRANPLAN.

SCREENLINES AND CUTLINES

Two screenlines were established, one N-S and one E-W, essentially bisecting the city of Tyler. Screenlines (SL) compare the total assigned volumes to the total ground counts (GC) of all links intersecting an imaginary line dividing the study area into two parts. Cutlines (CL) are similar to screenlines but intersect links of a travel corridor rather than the entire study area. This measure is somewhat more precise than screenlines in that it evaluates the assignment's ability to replicate travel on a more narrowly-defined travel corridor. Five cutlines were established on the Tyler network. The positions of the two screenlines and the five cutlines are shown in Figure 2. Table 1 shows the results of the total assigned volumes crossing the two screenlines and the five cutlines.

Table 1
Total Screenline and Cutline Assigned Volumes

	# of Links	GC	AON	STO	ITE	INC	EQU
SL1	20	211100	204773	209523	195121	208252	210363
SL2	17	146300	158860	154927	158234	155159	155512
CL1	6	37700	38325	36317	39220	35863	33804
CL2	6	56800	55783	55830	56173	54380	53912
CL3	4	42500	37644	38765	38357	43143	41980
CL4	7	87100	94194	92536	95121	88982	90742
CL5	9	91400	83805	86959	80457	86397	83666

The assigned volumes using the five techniques were compared to the ground counts and converted to a percent difference such that a positive value indicated an over-assignment compared to the ground counts. Table 2 shows the percent differences for the two screenlines and the five cutlines. In this research, assigned volumes were considered acceptable if they were within a ±20 percent difference from the ground counts.

The average percent differences for only the all-or-nothing assignment technique were slightly over-assigned with the least differences from the ground counts. Assigned volumes for the five assignment techniques ranged from an over-assignment of 9.21 percent to an under-assignment of 11.97 percent. All were within ±20 percent. Based on screenline and cutlines analyses, there are no significant differences between the total assigned volumes from the five assignment techniques and the total volumes from the ground counts.

Table 2
Percent Differences in Comparison to Ground Counts

	# of Links	GC	AON	STO	ITE	INC	EQU
SL1	20	211100	-3.00	-0.75	-7.57	-1.35	-0.35
SL2	17	146300	8.59	5.90	8.16	6.06	6.30
CL1	6	37700	1.66	-3.67	4.03	-4.87	-1.03
CL2	6	56800	-1.79	-1.71	-1.10	-4.26	-5.08
CL3	4	42500	-1.14	-8.79	-9.75	1.51	-1.22
CL4	7	87100	8.14	6.24	9.21	2.16	4.18
CL5	9	91400	-8.31	-4.86	-11.97	-5.47	-8.46
	Average Differences		0.59	-1.09	-1.28	-0.89	-0.81
	Standard Deviations		6.10	5.53	8.69	4.32	5.04

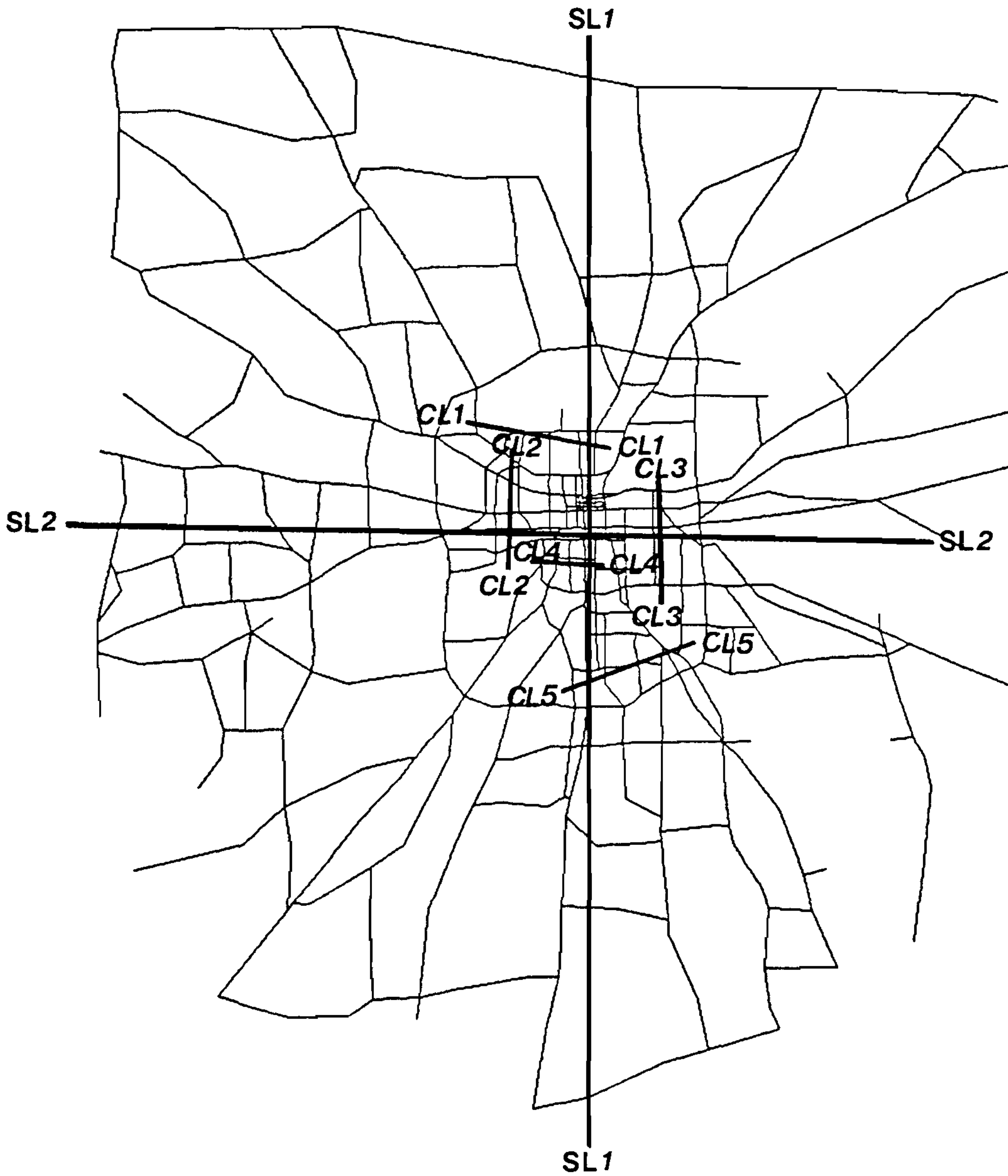


FIGURE 2. Selected Screenlines and Cutlines.

VEHICLE-MILES OF TRAVEL

Vehicle-miles of travel (VMT) for each link were calculated by multiplying the length of the link by its respective assigned volume or ground count. The total VMT was calculated. Based on the functional classification (FC) and the jurisdiction (JD) groups, the total VMT for each group for each of the assignment techniques was divided by the VMT for that group of the ground counts. Figure 3 shows the locations of the jurisdictions; the functional classifications and jurisdiction groups are shown in Table 3.

Table 3
Functional Classification and Jurisdiction Codes

Code	Identification
FC1.	Interstate Freeway
FC2.	Divided or Undivided 6-lane Urban Arterial
FC3.	Divided or Undivided 4-lane Urban Arterial
FC4.	One-way 2-lane Urban Arterial or Collector
FC5.	Undivided 2-lane Urban Arterial
FC12.	Divided 4-lane or Undivided 6-lane Rural Highway
FC14.	Undivided 2-lane Rural Highway
JD1.	CBD
JD2.	North of Urban
JD3.	South of Urban
JD4.	South-West Suburban and Rural
JD5.	North-West Suburban and Rural
JD6.	North Suburban and Rural
JD7.	North-East Suburban and Rural
JD8.	South-East Suburban and Rural

Table 4 gives a summary of the ratio of assigned compared to the ground count VMT for links in the network based on functional classification and jurisdiction groups.

Table 4
VMT Ratio in Comparison to Ground Counts

Group Codes	VMT for GC	AON	STO	ITE	INC	EQU
FC1.	273000	0.96	0.95	0.96	0.95	0.95
FC2.	332805	1.02	0.99	1.00	0.94	0.99
FC3.	732970	0.99	1.00	0.99	0.99	0.99
FC4.	137102	0.96	0.92	1.02	1.11	0.97
FC5.	91363	1.04	1.10	1.08	1.09	1.07
FC12.	593990	1.06	1.05	1.05	1.04	1.04
FC14.	500979	0.98	1.00	0.98	1.04	1.02
Average VMT	380316	1.00	1.00	1.01	1.02	1.00
JD1.	45394	1.04	1.15	1.02	1.01	0.99
JD2.	397430	0.98	0.95	0.99	1.00	0.99
JD3.	723997	1.04	1.06	1.03	1.03	1.03
JD4.	319901	0.98	0.98	0.99	0.99	0.99
JD5.	253839	0.96	0.98	0.96	1.03	1.02
JD6.	517421	1.01	1.00	1.01	0.99	0.99
JD7.	98663	1.01	1.00	1.01	1.01	0.97
JD8.	305564	0.99	0.99	0.99	1.00	0.97
Average VMT	332776	1.00	1.01	1.00	1.01	0.99

The degree to which the assigned VMT matched the VMT for the ground counts was measured by the ratio. A value greater than 1.0 indicated an over-assignment. Like the results of the previous macro-level analysis, the ratio measures of the VMT resulted in no significant differences among the assignment techniques. An overall view of the results of the three macro-level measures for the five assignments generated by using different techniques compared to the ground counts leads to the following three observations:

1. There is no significant difference among the results of the five assignment techniques.
2. All five assignment techniques gave very good results (within acceptable ranges) when compared to the ground counts.
3. All three measures (screenlines, cutlines, and VMT) were effective for the comparisons of traffic assignment techniques.

FIGURE 3. Sector Map by Jurisdiction.

MICRO-LEVEL ANALYSES

The micro-level measures of assignment accuracy consisted of several tests that utilized link-by-link differences between ground counts and assigned volumes. For the micro-level measures, a total of 1,686 one-way directional links were used.

DISTRIBUTION OF DIFFERENCES BY ERROR RANGES

The differences between assigned and counted link volumes were tabulated for each link by absolute error ranges (±500, ±1000, ±2000, and over 2000 vpd) and by percent error ranges (±10, ±25, ±50, ±100, and over 100 percent) for the five assignment techniques. The results are shown in Table 5. The accumulated number of links in each range was converted to a percentage of the total links. The distribution of differences by error ranges gives a perspective of the dispersion of error.

Table 5
Distribution of Differences by Error Ranges
(All Values in Percent)

	Absolute Error (vpd)				Percent Error				
Tech.	±500	±1000	±2000	±2000+	±10.0	±25.0	±50.0	±100	±100+
*** Number of Links ***									
AON	885	285	327	189	495	449	401	294	47
STO	930	306	301	149	538	512	326	239	71
ITE	904	319	296	167	554	460	359	258	55
INC	987	355	247	97	597	506	335	180	68
EQU	955	340	259	132	573	451	363	244	55
*** Percentages ***									
AON	52.5	16.9	19.4	11.2	29.4	26.6	23.8	17.4	2.8
STO	55.2	18.1	17.9	8.8	31.9	30.4	19.3	14.2	4.2
ITE	53.6	18.9	17.6	9.9	32.9	27.3	21.3	15.3	3.3
INC	58.5	21.1	14.7	5.8	35.4	30.0	19.9	10.7	4.0
EQU	56.6	20.2	15.4	7.8	34.0	26.7	21.5	14.5	3.3
*** Accumulated Percentages ***									
AON	52.5	69.4	88.8	100	29.4	56.0	79.8	97.2	100
STO	55.2	73.3	91.2	100	31.9	62.3	81.6	95.8	100
ITE	53.6	72.5	90.1	100	32.9	60.1	81.4	96.7	100
INC	58.5	79.6	94.2	100	35.4	65.4	85.3	96.0	100
EQU	56.6	76.8	92.2	100	34.0	60.7	82.3	96.7	100

Absolute and percent errors give two slightly different views of the same data. For percent error, the magnitude of the error is relative to the volume of the given link. An over- or under-assignment of 500 vpd on a link with a counted volume of 500 vpd (100 percent error) is much more significant than an over- or under-assignment of 500 vpd on a link with a counted volume of 10000 vpd (5 percent error). Thus, while both examples have an absolute error of 500 vpd, one would be good and one poor on a percent error basis. Percent error is a better relative measure on a link-by-link basis. Generally, the values in Table 5 increased slightly from the all-or-nothing to the equilibrium assignment techniques. The values from the incremental assignment indicated the best results compared to ground counts. However, the differences among the five techniques are insignificant.

DISTRIBUTION OF DIFFERENCES BY VOLUME GROUPS

To further investigate the distribution of differences between assigned and counted link volumes, the network links were divided into 21 counted volume groups. Table 6 shows the distribution of the 1686 links by the volume group. The largest number of links were assigned to the volume group of 0-1000 vpd. It is interesting to note that all five techniques had a higher number of links which differed significantly from the ground counts in the 20001-over vpd volume group.

Table 6
Distribution of Links by Volume
(All Values in Number of Links)

Volume Group	Count	AON	STO	ITE	INC	EQU
0- 1000	474	544	475	506	438	482
1001- 2000	258	211	254	240	263	234
2001- 3000	150	110	133	113	144	157
3001- 4000	126	122	131	121	143	128
4001- 5000	110	141	115	143	108	107
5001- 6000	66	78	97	80	91	67
6001- 7000	106	83	95	80	86	108
7001- 8000	74	74	90	83	93	95
8001- 9000	74	69	59	61	91	70
9001-10000	64	47	35	55	51	50
10001-11000	40	40	37	42	30	33
11001-12000	54	25	32	33	35	29
12001-13000	20	35	30	28	33	37
13001-14000	8	16	18	14	14	17
14001-15000	6	13	16	13	10	11
15001-16000	8	14	6	16	14	8
16001-17000	4	14	7	8	4	9
17001-18000	14	4	6	4	0	2
18001-19000	6	6	10	8	6	8
19001-20000	12	4	2	10	10	6
20001- Over	12	36	38	28	22	28

The ground counted volume groups for the 1686 links are summarized as follows:

1 - 1000 vpd	=	474 links	=	28.1% of total links
1001 - 5000 vpd	=	644 links	=	38.2% of total links
5001 - 10000 vpd	=	384 links	=	22.8% of total links
OVER 10000 vpd	=	184 links	=	10.9% of total links
TOTAL	=	1686 links	=	100.0%

The distribution of differences by error ranges, absolute and percent, were analyzed by tabulating the data by four counted volume groups (see Table 7). Generally, the percentage values of absolute error decreased with increasing volume group. For example, 91.4 percent of the links from the all-or-nothing assignment having counted volumes of 0-1000 vpd were within ±500 vpd, while only 16.3 percent of the links having counted volumes over 10000 vpd were within ±500 vpd. With the exception of the over 10000 vpd volume group, the trend was exactly the opposite for the values of percent error in which the respective values of percent error increased as the volume group increased.

Unlike the results of the previous measure, the values in Table 7 do not show a consistent increase from AON to EQU. For the 0-1000 vpd volume group, there was no significant difference among the five assignment results in both absolute errors and percent errors. The percentage values of the incremental assignment indicated the best results among other assignment techniques in the 1001-5000 vpd, 5001-10000 vpd, and 10001-over volume groups. In the high volume groups, which are more significant for the analysis of the traffic assignment accuracy than the low volume groups, the incremental assignment had the best results.

Again, the values for the incremental assignment had the best results compared to the ground counts in all three volume groups. The values for the all-or-nothing and stochastic multipath assignments were slightly better than the results of other assignments in lower volume groups. The values of the equilibrium assignment were very similar to the values of the incremental assignment in all four volume groups. However, there was no significant difference among the five assignment techniques based on the overall analyses by the volume groups.

Table 7
Distribution of Link Differences by Error Ranges for Counted Volume Groups

0-1000 vpd Volume Group.

Tech.	Absolute Error (vpd)				Percent Error (%)				
	±500	±1000	±2000	±2000+	±10.0	±25.0	±50.0	±100	±100+
AON	91.4	97.9	99.6	100.0	17.3	34.2	61.4	93.5	100.0
STO	90.3	96.2	99.8	100.0	16.9	37.6	62.2	90.3	100.0
ITE	89.9	97.9	99.6	100.0	19.8	39.2	63.9	93.0	100.0
INC	89.5	98.5	100.0	100.0	15.6	36.7	64.8	89.2	100.0
EQU	89.2	99.2	100.0	100.0	15.8	33.1	63.1	92.2	100.0

1001-5000 vpd Volume Group.

Tech.	Absolute Error (vpd)				Percent Error (%)				
	±500	±1000	±2000	±2000+	±10.0	±25.0	±50.0	±100	±100+
AON	46.7	71.0	93.8	100.0	27.8	52.6	78.6	97.5	100.0
STO	52.3	76.9	95.5	100.0	32.3	59.9	81.7	96.1	100.0
ITE	50.6	74.5	94.7	100.0	31.4	56.2	80.7	97.2	100.0
INC	55.6	82.3	97.0	100.0	30.3	63.2	87.7	97.4	100.0
EQU	53.3	77.5	93.8	100.0	30.7	57.3	81.7	97.2	100.0

5001-10000 vpd Volume Group.

Tech.	Absolute Error (vpd)				Percent Error (%)				
	±500	±1000	±2000	±2000+	±10.0	±25.0	±50.0	±100	±100+
AON	31.5	52.6	84.1	100.0	44.0	80.5	96.9	100.0	100.0
STO	35.9	59.4	91.1	100.0	46.4	88.8	98.2	100.0	100.0
ITE	31.5	58.9	88.3	100.0	47.7	84.1	96.4	99.0	100.0
INC	44.0	71.4	94.5	100.0	59.1	93.8	99.5	100.0	100.0
EQU	39.6	65.4	93.2	100.0	52.6	90.1	99.0	100.0	100.0

10001-over vpd Volume Group.

Tech.	Absolute Error (vpd)				Percent Error (%)				
	±500	±1000	±2000	±2000+	±10.0	±25.0	±50.0	±100	±100+
AON	16.3	25.5	53.3	100.0	35.3	72.8	95.7	100.0	100.0
STO	14.7	31.0	53.8	100.0	39.1	78.8	96.7	100.0	100.0
ITE	16.8	28.8	53.3	100.0	40.8	77.7	97.8	100.0	100.0
INC	19.6	38.6	69.0	100.0	54.9	88.0	100.0	100.0	100.0
EQU	20.1	40.8	64.1	100.0	53.3	82.6	98.9	100.0	100.0

STATISTICAL MEASURES OF LINK DIFFERENCES

A total of 1686 directional links were used to compute the measures of link differences. The counted volumes were subtracted from the respective assigned volume for each assignment technique. Figure 4 is a frequency distribution of the link differences in intervals of 1000 vpd, theoretically centered about zero, and spread over the range between the largest negative difference and the largest positive difference.

Five statistical measures, mean difference (MD), standard deviation (SD), root-mean-square (RMS) error, percent root-mean-square (PRMS), and percent standard deviation (PSD) were employed in the evaluation of link differences. FORTRAN programs were used for the statistical measures of link differences and are shown in Appendix A. Table 8 summarizes the results of the statistical measures of link differences.

Table 8
Statistical Measures of Link Differences

Techniques	Mean Volume	MD	SD	RMS	PRMS	PSD
AON	4425	98	2183	2185	50.5	50.5
STO	4463	136	1911	1915	44.3	44.2
ITE	4425	98	2098	2100	48.5	48.5
INC	4421	94	1544	1546	35.7	35.7
EQU	4404	77	1833	1834	42.4	42.4

Mean Difference

The mean difference varied from 77 vpd to 136 vpd. This indicated that all five assignment techniques resulted in over-assigned trips. The assignment was more overloaded in the stochastic multipath technique than other techniques, while the equilibrium assignment was the least over-assigned. The mean counted volume was 4327 vpd.

Standard Deviation

The standard deviation varied from 1544 vpd to 2183 vpd. Theoretically, a perfect assignment (i.e., one that did not differ from the counted volumes) would have a standard deviation of zero. The better the assignment, the greater the tendency of the frequency distribution of link differences curve to peak at zero and the lesser the tendency for the curve to spread.

The incremental assignment peaked higher (102 links more than the all-or-nothing and 83 links more than the iterative) and is somewhat less spread than other techniques. The incremental assignment had a higher peak at zero volume difference than the other assignments; however, it was skewed to the right (positive difference). The distribution of the equilibrium assignment balanced evenly between negative and positive differences and with less spread (dispersion).

The tendency to peak at zero is a necessary, but insufficient, indicator of the goodness of the assignment. The standard deviation is a good indicator of the closeness of the fit between assigned and counted volumes. The standard deviation is affected by a small proportion of links with large differences. Comparison of Figure 4 and Table 8 shows that the standard deviation is sensitive to the tails of the distribution of link volume differences. However, only a small proportion had 3000 or over vpd differences.

Root-Mean-Square Error

Table 8 shows that the root-mean-square error is very similar to the standard deviation in that it is a measure of dispersion. The RMS error is a measure of the dispersion of the differences relative to a zero difference, whereas the standard deviation is relative to the mean difference. The mean difference of 136 vpd for the stochastic multipath assignment technique results in a difference of four vpd (1911 versus 1915) between SD and RMS. The small mean difference of 77 vpd for the equilibrium results in only one (1833 versus 1834) vpd difference. Based on the Tyler network using the five different assignment techniques, the RMS error does not give a better indication of the goodness of the assignment than the standard deviation of the differences.

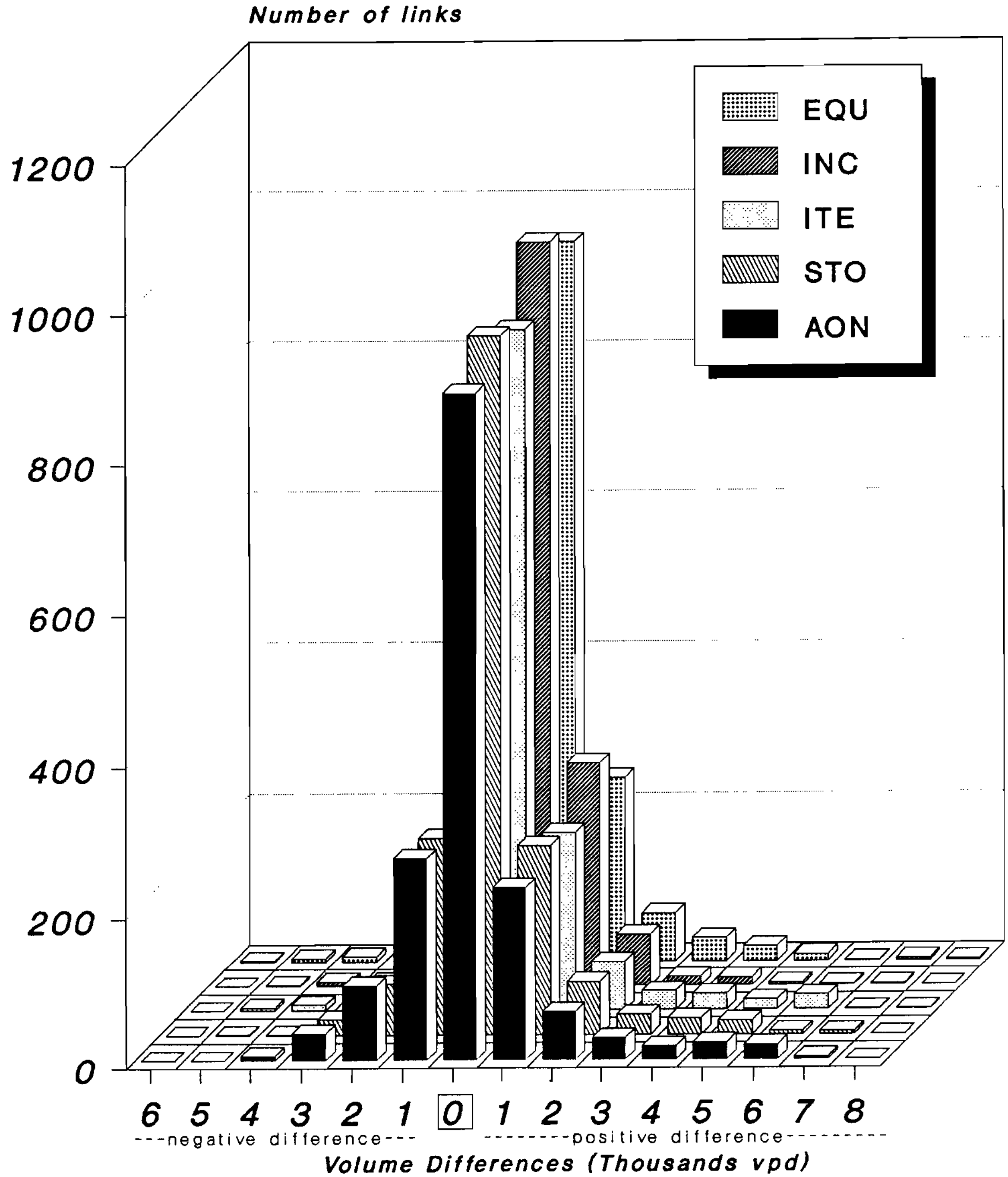


FIGURE 4. Frequency Distribution of Link Volume Differences.

Percent Root-Mean-Square Error

The percent root-mean-square error measures the relationship between RMS error and the average counted volume. Since the counted volume remains the same for a given network, the average counted volume is a constant and the PRMS error is simply the RMS error divided by 4327 vpd. The incremental assignment had the smallest PRMS error, and the all-or-nothing assignment had the highest. The other three assignment techniques were judged to be equivalent.

Since the PRMS error is a suitable statistic for comparing assignments of different networks for varying network size and volume, the degree of goodness of the results needs to be established for comparing the five assignments in the Tyler network with the other assignments. Such a standard might be established by relating the Tyler assignments to several modeled assignments. Table 9 shows the average counted link volumes and the PRMS error for the all-or-nothing and the weighted multiple path (WMP) assignments in different cities. The WMP assignment procedure that was used produces an assignment in which the assigned volumes are in relative balance with the traffic counts, not with the link capacity. This is accomplished through an iterative technique whereby the link impedances are adjusted between iterations.

Table 9
Percent RMS Error in Different Networks

NETWORK	MEAN VOLUME	PRMS of AON	PRMS of WMP
San Angelo	5091	58.1	26.3
Houston-Galveston	10356	65.5	32.3
Texarkana	4382	67.1	42.4
Wichita Falls	5978	72.9	28.5
Abilene	3871	77.0	36.7
Lubbock	7843	80.9	25.4
McAllen-Pharr	3636	83.0	49.5
Amarillo	7200	85.4	32.3
Corpus Christi	7628	90.2	35.0
Laredo	4280	93.0	76.1

Source: Stover, Buechler, and Benson. A Sensitivity Evaluation of Traffic Assignment. TTI, 1975 (6).

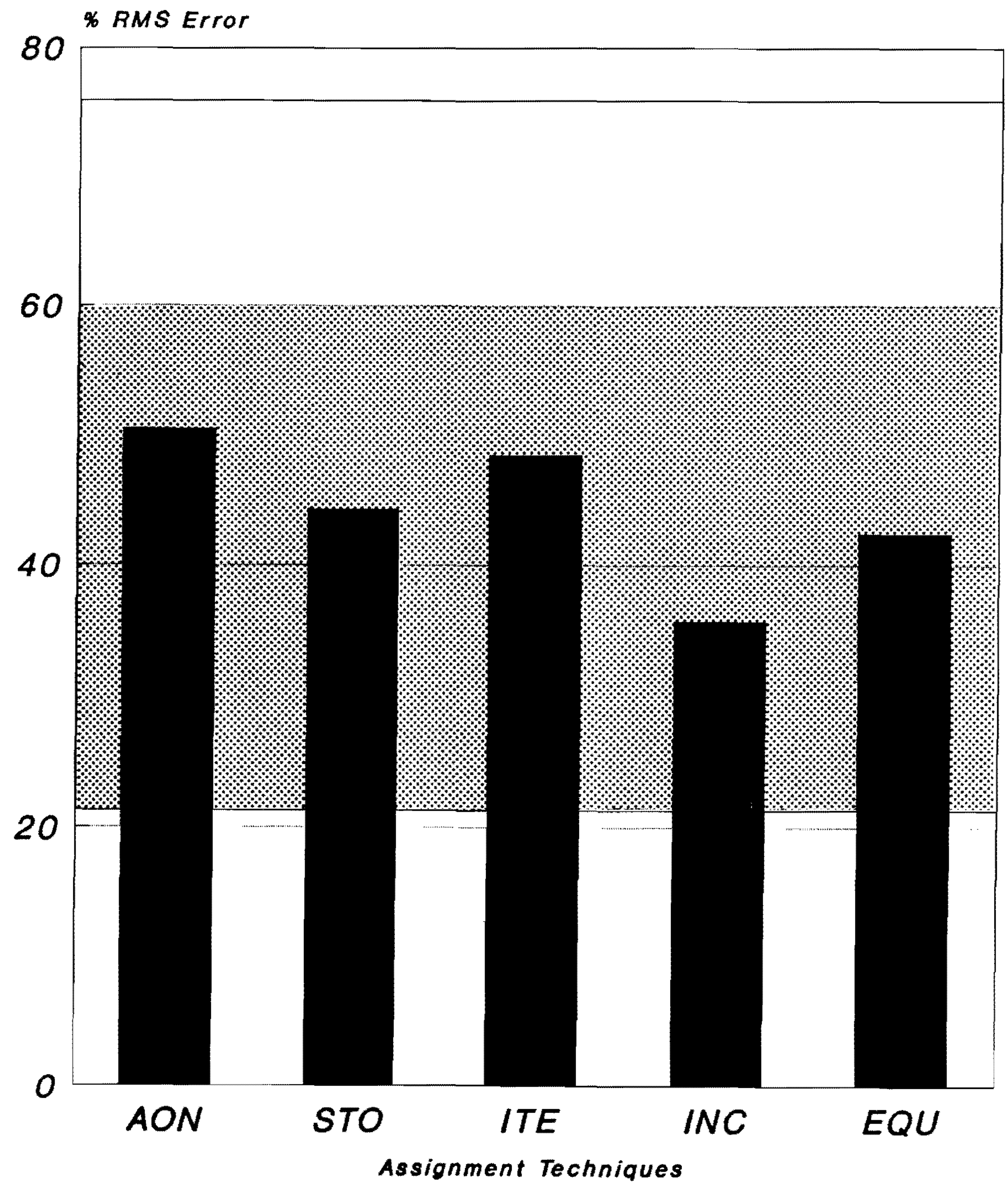
Table 9 shows the average counted volumes ranged from 3636 vpd to 10356 vpd in the 10 selected networks, while the Tyler network had an average counted volume of 4327 vpd. For all five assignments (Tables 8 and 9), the results compare favorably with the other study networks. Values of PRMS error were also analyzed for these networks for the WMP assignments; the WPM is similar to the incremental assignment technique. The values of PRMS for the WMP assignment ranged from 25.4 percent to 76.1 percent. Again, the assignments from all five techniques compare as favorably in the weighted assignment as they did in the all-or-nothing assignment.

Interestingly, there was considerable change in the relative rankings of the assignments from the all-or-nothing assignment to the WMP assignment. For instance, Lubbock went from the seventh best value in the all-or-nothing assignment to the second best value in the WMP assignment. The improvements in PRMS range between 17 and 56 percentage points in the 10 networks. The Tyler network indicated only a small improvement of 14.8 percent (50.5 versus 35.7) from the all-or-nothing to the incremental assignment. Figure 5 shows the PRMS errors for the five assignment results. Graphically, all five assignments of the Tyler network are well within the PRMS errors for the other study networks as shown in Figure 5.

Percent Standard Deviation

The percent standard deviation measures the relationship between the standard deviation and the average counted volume. Since the counted volume remains the same for a given network, the average counted volume is a constant and the percent standard deviation is simply the SD divided by the constant of 4327 vpd. All five assignment techniques have PSDS similar to their PRMS error.

To give additional support to the acceptability of the assignments in the Tyler network, Table 10 shows the percent standard deviation of traffic assignments for 10 cities outside of Texas. Humphrey (7) states that PSD and PRMS are in reasonable agreement. The PSDs range from 30.9 percent to 55.3 percent for the 10 cities.



Note: ▒ Indicates percent RMS error ranges using weighted multiple path assignments from 10 selected cities.

FIGURE 5. Distribution of Percent RMS Error by Link Differences.

Table 10
Percent Standard Deviation for Selected Non-Texas Cities

City	PSD	City	PSD
Salem, OR	41.8	Salt Lake City, UT	38.0
Sioux Falls, SD	49.1	Honolulu, HI	53.5
Green Bay, WI	49.4	Portland, OR	55.3
Madison, WI	30.9	Atlanta, GA	39.0
Tucson, AZ	47.7	Denver, CO	44.4

Note: Above results are averages of 3 to 5 iterations.
Source:Humphrey, A Report on the Accuracy of Traffic Assignment When Using Capacity Restraint, HRR 191 (7).

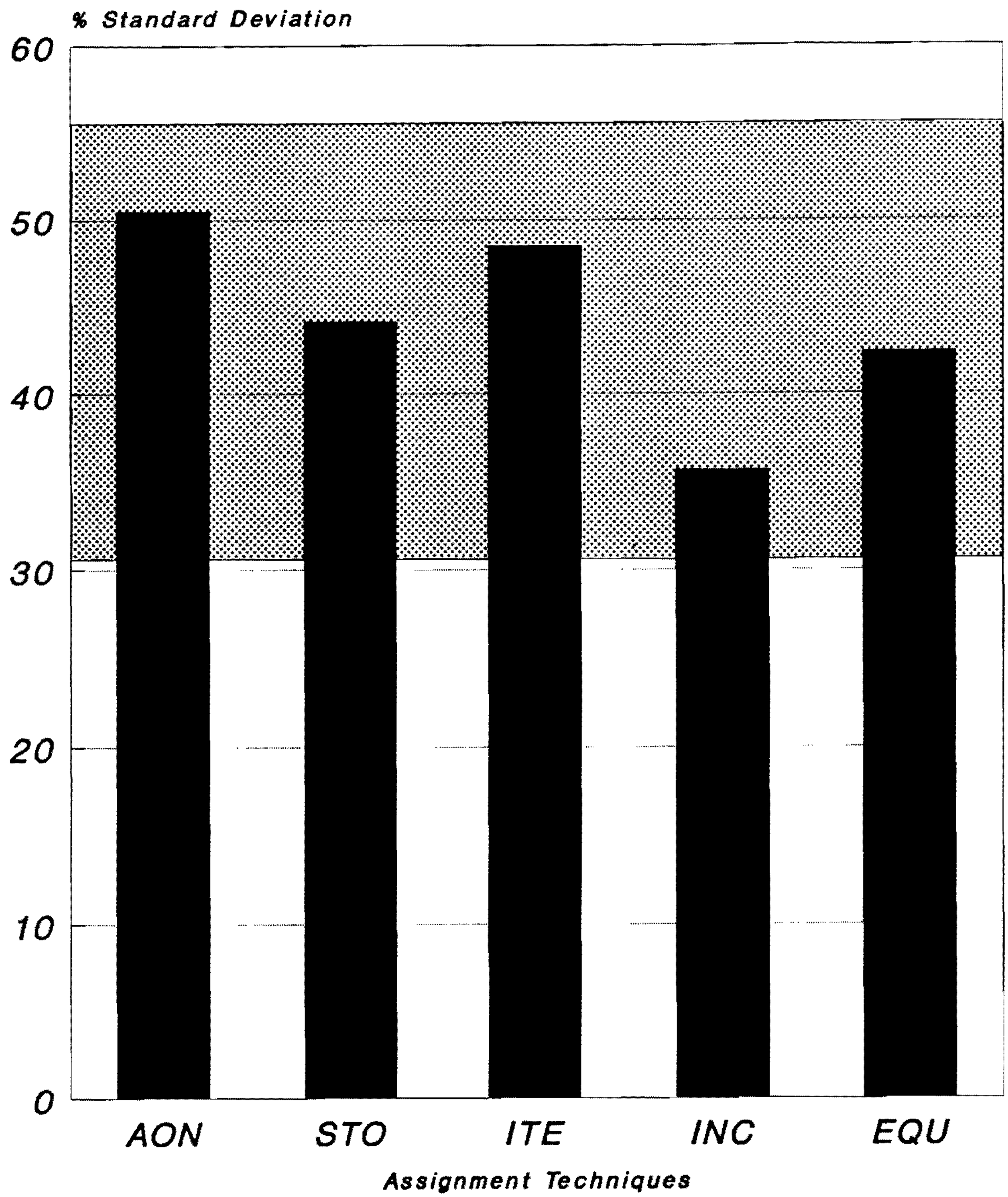
The five assignments for the Tyler network have similar values of PSD compared to the values of the 10 selected cities. Figure 6 shows PSD for the five assignment results. Also, the shaded area in Figure 6 represents the results of PSD for the other 10 study networks. Graphically, all five values of the Tyler network were within the PSD ranges for the 10 cities.

In conclusion, a comparison of the statistical values for the five assignment techniques indicates there is no meaningful difference among the five assignment techniques. The introduction of capacity restraint using the iterative, incremental, and equilibrium assignments reduced the tendency toward over-assignment. It resulted in less difference from the ground counted volumes but had only a minor effect.

STATISTICAL TEST OF LINK DIFFERENCES

The X^2 goodness-of-fit test was employed to determine if any of the differences between assigned and counted volumes are statistically significant and/or to compare if any of the five assignment techniques are statistically significant. The FORTRAN programs are shown in Appendix B.

The X^2 goodness-of-fit tests were performed using volume group intervals and comparing the number of links (assigned and counted) in each volume group. The null hypothesis was that the distribution of assigned link volumes is the same as counted link volumes. The null hypothesis (H_o) was defined so that all link counts in each volume group



Note: ░░░ Indicates the ranges using capacity-restraint assignment from 10 selected non-Texas cities.

FIGURE 6. Distribution of Percent Standard Deviation by Link Differences.

(between the assigned volumes and the counted volumes) are the same. The alternative hypothesis (H_a) was that the cell counts in each volume group are independent of ground counts. The expected cell counts (E_i) were the number of links with ground counts in volume group "i". The observed cell counts (O_i) were the number of links in volume group "i" for each from the five assignment techniques. The number of links for the ground counted volumes and the assigned volumes of the five assignments were tabulated using volume group intervals of 1000 vpd in Table 11. Volume group 16001 vpd to 17000 vpd was combined with volume group 17001 vpd to 18000 vpd. A minimum cell value of five is recommended for the X^2 goodness-of-fit test.

Table 11
Distribution of Links by Volume Group for Chi-Square Test
(All Values in Number of Links)

Volume Group	Count	AON	STO	ITE	INC	EQU
0- 1000	474	544	475	506	438	482
1001- 2000	258	211	254	240	263	234
2001- 3000	150	110	133	113	144	157
3001- 4000	126	122	131	121	143	128
4001- 5000	110	141	115	143	108	107
5001- 6000	66	78	97	80	91	67
6001- 7000	106	83	95	80	86	108
7001- 8000	74	74	90	83	93	95
8001- 9000	74	69	59	61	91	70
9001-10000	64	47	35	55	51	50
10001-11000	40	40	37	42	30	33
11001-12000	54	25	32	33	35	29
12001-13000	20	35	30	28	33	37
13001-14000	8	16	18	14	14	17
14001-15000	6	13	16	13	10	11
15001-16000	8	14	6	16	14	8
16001-18000	18	18	13	12	4	11
18001-19000	6	6	10	8	6	8
19001-20000	12	4	2	10	10	6
20001- Over	12	36	38	28	22	28

The calculated X^2 values for the five assignment techniques are shown in Table 12.

Table 12
Summary of Calculated Chi-Square Values

Techniques	AON	STO	ITE	INC	EQU
Chi-Square	151.28	150.34	93.10	78.93	81.36

The computed values of X^2 for all the assignments are greater than 27.2036, the tabulated critical value of the X^2 statistic for $\alpha = 0.10$ and $df = 19$. The H_o was rejected, and it was concluded that at least one of the cell counts in the volume group differs from the link counts with ground counts in that volume group. There is a significant difference between counted and assigned volumes for the five assignments. In other words, none of the five assignment techniques was distributed in the same manner as ground counts.

The incremental technique (the smallest X^2 value of 78.93) resulted in the best fit. The all-or-nothing and the stochastic techniques (the largest values of 151.28 and 150.34, respectively) produced the worst fit. The assignments improved from the all-or-nothing and the stochastic techniques to the iterative, equilibrium, and incremental techniques.

SUMMARY OF MICRO-LEVEL ANALYSES

The various micro-level measures of assignment accuracy analyzed the differences between the counted volumes and the assigned volumes on a link-by-link basis for each of the five assignment techniques. Unlike the results of macro-level analyses, the micro-level measures were found to yield the various results. The evaluation of the micro-level measures leads to the following observations:

1. The incremental assignment gave the best results. The incremental and the equilibrium assignment techniques gave similar results with the incremental assignment usually being slightly better.
2. Generally, the three capacity-restraint assignments were better than the results of the all-or-nothing and the stochastic multipath assignments.
3. The assignments using the all-or-nothing and the stochastic multipath techniques generally gave similar results. Thus, it was found that the trip impedance

constraint to find multiple paths instead of the single shortest path had little effect on the Tyler network in micro-level measures.

Table 13 summarizes the results of the micro-level analyses using relative values as rankings. For example, in the first line of Table 13, the incremental assignment was given a rank of 5 indicating that it had the least absolute error, while the all-or-nothing assignment was given a rank of 1 indicating that it had the highest absolute error.

Table 13
Summary of Micro-Level Measures by Rankings

Measures	AON	STO	ITE	INC	EQU
Absolute Error	1	3	2	5	4
Percent Error	2	3	3	5	4
Difference by Volume Group	3	3	3	5	4
Mean Difference	4	3	4	4	5
Standard Deviation	3	4	3	5	4
Root-Mean-Square Error	3	4	3	5	4
Chi-Square Value	2	2	4	5	4
Sum of Rankings	18	22	22	34	29

Note: The higher rank indicates the closer assigned volume to the ground count.

The results of the incremental assignment marked the highest total ranks in all five assignment techniques. The incremental assignment was better than the ranks of the equilibrium assignment with the exception of the mean difference analysis. The stochastic multipath assignment was the same as the iterative assignment and slightly better than the all-or-nothing assignment technique.

It was concluded that the equilibrium and incremental assignment techniques produced better results than the all-or-nothing and the stochastic multipath techniques, but the difference in results was of no practical significance when using capacity restraint. In order for capacity restraint to be effective, a large number (or large proportion) of links must have volumes near, at, or over capacity. Obviously, capacity restraint was not effective because the assignment used in this research was made in the existing network for existing trips which are much lower than the capacity.

SUMMARY AND CONCLUSIONS

SUMMARY

This research compared the five different assignment techniques: all-or-nothing, stochastic multipath, iterative, incremental, and equilibrium. The two research objectives were (1) to determine whether there was a significant difference between the assigned volumes obtained from the five different techniques and (2) to compare assigned volumes with ground counts.

The five assignments were compared to ground counts to determine if there was a difference among the results. Measures of how well the assignment reproduced ground counts were divided into two groups: macro-level measures (screenlines, cutlines, and VMT) which are network wide analyses and micro-level measures (absolute link volumes, percent link volumes, link volumes by counted volume groups, mean, standard deviation, and percent RMS error differences) which are link-by-link comparisons.

CONCLUSIONS

An overall view of the results leads to the following four observations:

1. There is no difference among the results of the five assignment techniques using the macro-level measures.
2. All five assignment techniques gave reasonable results based on the three macro-level measures.
3. The incremental assignment produced the best results based on the micro-level measures. The equilibrium assignment was almost as good as the incremental assignment.
4. A comparison of the statistical values for the five assignment techniques indicates there is no significant difference among the different assignment techniques in the Tyler network. The introduction of capacity restraint using the iterative, incremental, and equilibrium assignments reduced the tendency toward over-assignment and resulted in less difference from the ground counted volumes but had a very minor effect.

In summary, the assignment procedure is a powerful tool in the modeling process for the evaluation of land-use and transportation system alternatives. Due to the aggregative nature of the assignment procedure, differences that were observed in the different assignment techniques tended to disappear in the assignment results. This implies that much of the precision in the assignment procedure using the different techniques may be sacrificed and still produce acceptable assignment results.

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APPENDIX A

TRANPLAN Output for Macro-Level Analyses

This appendix presents the output files for the macro-level analysis using the Report Highway Network Summary program of TRANPLAN. The TRANPLAN output files were slightly modified. Three measures of assignment accuracy at the macro-level were utilized in evaluating the results of the five assignment techniques. The three measures of assignment accuracy at the macro-level were:

- o Two Screenlines
- o Five Cutlines
- o VMT by Functional Classifications and by Jurisdictions

REPORT HIGHWAY NETWORK SUMMARY
SCREENLINES AND CUTLINES IN TYLER (252 ZONES) DATE 02AUG88
FOR LOADING USING TEXAS TRIP TABLE TIME 09:42:45

SCREEN LINE NO. 1

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
333	334	74	70	76	78	81	150
333	389	505	591	616	798	815	850
334	333	77	75	82	85	86	150
388	393	6223	5683	6375	6867	6785	6450
389	333	503	591	500	772	809	850
393	388	6285	5767	6476	6836	6648	6450
403	404	7967	7961	7964	8019	8023	8350
404	403	7953	7949	7953	8003	8019	8350
486	496	9451	6845	9191	9313	10106	8350
489	492	4352	4265	4656	4573	4105	4000
492	489	4474	4302	4890	4634	4144	4000
496	486	9497	6951	8972	9302	9921	8350
607	608	91	1550	116	1428	1887	3350
608	607	108	1544	116	1470	1831	3350
614	616	4814	5500	4766	4771	4440	5250
616	614	4980	5465	4585	4980	4660	5250
625	627	8281	9954	8408	9052	8258	9000
627	625	8241	9786	7894	8744	7540	9000
637	647	9612	9368	10085	9160	9876	10700
640	645	583	1096	583	624	566	800
641	642	3933	5123	4327	3934	4371	5200
642	641	3909	4884	4006	3656	4374	5200
645	640	583	1156	583	625	568	800
647	637	9650	9446	10073	9184	9811	10700
788	789	22166	23473	20991	23410	26587	22000
789	788	22143	23536	20980	23155	26587	22000
791	793	3499	3452	3308	4274	4070	3400
793	791	3486	3087	3275	4264	4502	3400
795	796	557	1951	626	716	751	600
796	795	558	1877	627	706	589	600
797	798	5958	4998	5741	6350	7076	4450
798	797	5955	5127	5739	6482	6804	4450
907	908	1126	1126	1126	1126	1126	1050
908	907	1123	1123	1124	1124	1124	1050
920	950	358	390	357	361	358	1000
935	936	5261	5076	1916	5267	5746	6850
936	935	5264	5081	1916	5321	5747	6850
947	948	7432	6378	6874	4204	597	3750
948	947	7389	6537	6861	4212	608	3750
950	920	352	389	367	372	367	1000
TOTAL =		204773	209523	195121	208252	210363	211100

SCREEN LINE NO. 2

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
567	568	14300	15492	15027	15526	18577	11150
568	567	14342	14464	14945	15602	14777	11150
576	577	241	502	238	1581	1662	1500
577	576	253	463	250	1630	1490	1500
577	578	4233	3201	4142	3683	214	3350
578	577	4169	4244	4156	3656	4129	3350
583	586	2647	2631	2313	2912	2741	1450
586	583	2630	2659	2291	2876	2855	1450
598	600	2633	2935	2792	2635	2709	4250
600	598	2613	2879	3008	2583	2768	4250
629	630	15309	13974	15133	12249	13398	8900
630	629	15310	13883	14401	11774	12915	8900
642	643	9478	11012	9422	8882	8008	9200
643	642	9587	10826	9176	8929	7554	9200
656	657	4321	3188	4129	3791	3638	3250
656	660	2789	4317	3641	4401	3783	5400
657	656	4330	3131	4142	3698	3665	3250
660	656	2833	4571	3637	4347	3953	5400
672	673	11822	9140	11574	10012	10985	11300
673	672	11878	9033	11552	10162	10998	11300
687	688	1194	1213	1333	1240	1321	1550
688	687	1206	1198	1346	1133	1011	1550
700	716	1067	985	393	875	1172	650
712	715	8236	7927	8338	8860	8792	9250
715	712	8274	8007	8400	8951	8831	9250
716	700	1053	967	388	864	1165	650
719	720	351	368	339	480	554	1000
720	719	348	360	335	477	548	1000
721	722	36	47	35	35	32	300
722	721	53	70	43	44	39	300
726	727	50	63	46	54	75	50
727	726	52	68	49	65	76	50
732	733	618	579	611	576	536	600
733	732	604	575	609	576	541	600
TOTAL =		158860	154972	158234	155159	155512	146300

CUT LINE NO. 1

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
447	459	1289	1503	1603	1434	1310	900
456	457	9480	8312	9498	7598	6614	8650
457	456	9529	8401	9667	7664	6711	8650
458	459	2230	2134	2314	2457	2464	3400
459	447	1361	1543	1616	1457	1317	900
459	458	2204	2073	2265	2406	2400	3400
461	462	2231	2436	2520	2395	2377	2550
462	461	2229	2525	2325	2389	2324	2550
487	488	1251	1226	1274	1248	1329	1200
488	487	1240	1300	1261	1240	1275	1200
492	495	2641	2422	2342	2788	2870	2150
495	492	2640	2442	2535	2787	2813	2150
TOTAL =		38325	36317	39220	35863	33804	37700

CUT LINE NO. 2

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
454	466	9906	9932	9939	9002	9145	10650
466	454	9855	9751	9828	8975	9040	10650
467	468	1766	1618	1713	1585	1769	1050
468	467	1785	1600	1745	1632	1801	1050
470	471	1199	1364	1228	1384	1266	2050
471	470	1198	1379	1235	1376	1342	2050
666	697	8272	6467	8529	7276	6660	6000
682	683	1319	1162	1343	1375	1437	1400
683	682	1327	1144	1353	1379	1448	1400
688	689	5445	7559	5457	6603	6667	7250
689	688	5418	7490	5407	6524	6667	7250
697	666	8293	6364	8396	7269	6670	6000
TOTAL =		55783	55830	56173	54380	53912	56800

CUT LINE NO. 3

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
525	526	598	646	669	779	753	1950
526	525	592	654	676	792	760	1950
536	538	4468	3434	4206	4508	4651	3050
538	536	4395	3432	4469	4693	4432	3050
582	583	6444	7716	5675	7170	7432	7250
583	582	6495	7633	5936	7420	7122	7250
589	590	7346	7660	8386	8920	8521	9000
590	589	7306	7590	8340	8861	8309	9000
TOTAL =		37644	38765	38357	43143	41980	42500

CUT LINE NO. 4

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
594	597	6653	6239	6695	5439	4256	5300
597	594	6642	6494	6649	5543	4485	5300
631	632	14376	13265	14225	11271	14414	10700
632	631	14400	13646	14242	10824	14210	10700
638	640	2026	3302	2041	4571	3279	3200
640	638	2032	3432	2052	4104	3390	3200
645	646	9862	9886	9688	8739	8687	9500
646	645	9754	9786	9651	8735	9135	9500
650	651	709	812	572	1010	692	1100
651	650	751	1030	535	979	643	1100
676	677	4959	5213	5840	5975	6182	6700
677	676	4950	5270	5820	5981	5930	6700
680	681	8566	7063	8520	7879	7726	7050
681	680	8514	7098	8591	7932	7713	7050
TOTAL =		94194	92536	95121	88982	90742	87100

CUT LINE NO. 5

A-NODE	B-NODE	AON	STO	ITE	INC	EQU	GROUND
787	805	3894	3343	6535	6405	6330	6350
788	790	16442	17732	13223	13398	13959	15500
790	788	16473	17606	13220	13468	13668	15500
805	787	3900	3324	6551	6413	6434	6350
819	821	161	594	747	1416	1219	3300
821	819	161	582	740	1387	1212	3300
825	826	0	380	0	0	0	300
826	825	0	371	0	36	0	300
828	848	598	607	647	1606	1135	2300
843	844	3026	2479	1208	5035	3486	3300
844	843	3122	2516	1226	5057	3485	3300
844	845	3559	3221	3644	3564	2970	1750
845	844	3653	3108	3632	3565	2936	1750
845	853	13878	13488	11116	9206	10363	10400
847	848	220	2017	3089	2456	2563	2500
848	828	593	550	615	1628	1231	2300
848	847	222	1951	3132	2535	2393	2500
853	845	13903	13090	11132	9222	10282	10400
TOTAL =		83805	86959	80457	86397	83666	91400

REPORT HIGHWAY NETWORK SUMMARY
VMT AND V/C RATIO BY FUNC.CLASS. AND BY JURISDICTION FROM SDHPT
FOR LOADING OF ALL-OR-NOTHING

TABLE UNITS -- VEHICLE - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	55047.5	206356.9	.0	.0	261404.3
2	.0	94712.4	93010.9	78437.3	.0	.0	.0	72049.0	338209.6
3	33914.9	144840.9	328990.0	13237.5	82990.2	24481.6	.0	94318.3	722773.4
4	4045.7	18108.4	63622.3	16366.5	.0	.0	.0	29049.7	131192.5
5	9226.8	40107.5	46044.1	.0	.0	.0	.0	.0	95378.5
12	.0	89304.0	192909.8	39114.1	40445.2	245397.4	.0	25380.7	632551.2
14	.0	3180.6	28614.2	165995.4	64540.7	46980.5	99733.2	81378.3	490422.8
TOTAL	47187.4	390253.8	753191.3	313150.8	243023.6	523216.4	99733.2	302175.9	2671933.0

TABLE UNITS -- CAPACITY2 - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	54800.0	218200.0	.0	.0	273000.0
2	.0	102089.0	76062.0	89564.0	.0	.0	.0	65090.0	332805.0
3	30555.0	148999.0	319626.0	16022.0	89517.0	23259.0	.0	104992.0	732970.0
4	3489.0	18485.0	78649.0	16371.0	.0	.0	.0	20108.0	137102.0
5	11350.0	39862.0	40151.0	.0	.0	.0	.0	.0	91363.0
12	.0	83497.0	179206.0	40438.0	40024.0	225744.0	.0	25081.0	593990.0
14	.0	4498.0	30303.0	157506.0	69498.1	50218.0	98663.0	90293.0	500979.1
TOTAL	45394.0	397430.0	723997.0	319901.0	253839.1	517421.0	98663.0	305564.0	2662209.0

TABLE UNITS -- VOLUME/CAPACITY2

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.00	.00	.00	.00	1.00	.95	.00	.00	.96
2	.00	.93	1.22	.88	.00	.00	.00	1.11	1.02
3	1.11	.97	1.03	.83	.93	1.05	.00	.90	.99
4	1.16	.98	.81	1.00	.00	.00	.00	1.44	.96
5	.81	1.01	1.15	.00	.00	.00	.00	.00	1.04
12	.00	1.07	1.08	.97	1.01	1.09	.00	1.01	1.06
14	.00	.71	.94	1.05	.93	.94	1.01	.90	.98
TOTAL	1.04	.98	1.04	.98	.96	1.01	1.01	.99	1.00

REPORT HIGHWAY NETWORK SUMMARY
VMT AND V/C RATIO BY FUNC.CLASS. AND BY JURISDICTION FROM SDHPT
FOR LOADING OF STOCHASTIC

TABLE UNITS -- VEHICLE - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	53448.7	206337.0	.0	.0	259785.6
2	.0	87520.1	91643.3	82816.6	.0	.0	.0	68375.5	330355.6
3	33314.5	142647.9	339860.5	13017.1	82602.9	24266.9	.0	96638.3	732348.0
4	4218.9	20294.8	64073.8	11637.6	.0	.0	.0	26390.3	126615.4
5	14847.0	40021.4	45721.0	.0	.0	.0	.0	.0	100589.3
12	.0	84414.1	196114.9	39462.9	40046.1	241124.1	.0	25363.8	626525.9
14	.0	3517.1	28635.8	164986.1	71813.3	45880.1	99126.9	85692.3	499651.4
TOTAL	52380.4	378415.4	766049.1	311920.3	247911.0	517608.0	99126.9	302460.2	2675872.0

TABLE UNITS -- CAPACITY2 - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	54800.0	218200.0	.0	.0	273000.0
2	.0	102089.0	76062.0	89564.0	.0	.0	.0	65090.0	332805.0
3	30555.0	148999.0	319626.0	16022.0	89517.0	23259.0	.0	104992.0	732970.0
4	3489.0	18485.0	78649.0	16371.0	.0	.0	.0	20108.0	137102.0
5	11350.0	39862.0	40151.0	.0	.0	.0	.0	.0	91363.0
12	.0	83497.0	179206.0	40438.0	40024.0	225744.0	.0	25081.0	593990.0
14	.0	4498.0	30303.0	157506.0	69498.1	50218.0	98663.0	90293.0	500979.1
TOTAL	45394.0	397430.0	723997.0	319901.0	253839.1	517421.0	98663.0	305564.0	2662209.0

TABLE UNITS -- VOLUME/CAPACITY2

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.00	.00	.00	.00	.98	.95	.00	.00	.95
2	.00	.86	1.20	.92	.00	.00	.00	1.05	.99
3	1.09	.96	1.06	.81	.92	1.04	.00	.92	1.00
4	1.21	1.10	.81	.71	.00	.00	.00	1.31	.92
5	1.31	1.00	1.14	.00	.00	.00	.00	.00	1.10
12	.00	1.01	1.09	.98	1.00	1.07	.00	1.01	1.05
14	.00	.78	.94	1.05	1.03	.91	1.00	.95	1.00
TOTAL	1.15	.95	1.06	.98	.98	1.00	1.00	.99	1.01

TABLE UNITS -- VEHICLE - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	54935.7	206341.4	.0	.0	261277.1
2	.0	93139.2	87644.5	79139.2	.0	.0	.0	72111.6	332034.6
3	33008.7	147882.8	327752.8	13977.8	85151.4	24754.1	.0	92848.4	725375.9
4	4135.2	18824.2	68740.5	19271.9	.0	.0	.0	29438.1	140409.9
5	9379.5	40335.3	48765.0	.0	.0	.0	.0	.0	98479.8
12	.0	89654.8	185541.8	40021.8	40354.1	245094.9	.0	25380.1	626047.4
14	.0	3158.1	28468.9	163399.3	64442.3	46818.0	99829.4	83629.4	489745.3
TOTAL	46523.4	392994.3	746913.6	315809.9	244883.5	523008.4	99829.4	303407.6	2673370.0

TABLE UNITS -- CAPACITY2 - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	54800.0	218200.0	.0	.0	273000.0
2	.0	102089.0	76062.0	89564.0	.0	.0	.0	65090.0	332805.0
3	30555.0	148999.0	319626.0	16022.0	89517.0	23259.0	.0	104992.0	732970.0
4	3489.0	18485.0	78649.0	16371.0	.0	.0	.0	20108.0	137102.0
5	11350.0	39862.0	40151.0	.0	.0	.0	.0	.0	91363.0
12	.0	83497.0	179206.0	40438.0	40024.0	225744.0	.0	25081.0	593990.0
14	.0	4498.0	30303.0	157506.0	69498.1	50218.0	98663.0	90293.0	500979.1
TOTAL	45394.0	397430.0	723997.0	319901.0	253839.1	517421.0	98663.0	305564.0	2662209.0

TABLE UNITS -- VOLUME/CAPACITY2

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.00	.00	.00	.00	1.00	.95	.00	.00	.96
2	.00	.91	1.15	.88	.00	.00	.00	1.11	1.00
3	1.08	.99	1.03	.87	.95	1.06	.00	.88	.99
4	1.19	1.02	.87	1.18	.00	.00	.00	1.46	1.02
5	.83	1.01	1.21	.00	.00	.00	.00	.00	1.08
12	.00	1.07	1.04	.99	1.01	1.09	.00	1.01	1.05
14	.00	.70	.94	1.04	.93	.93	1.01	.93	.98
TOTAL	1.02	.99	1.03	.99	.96	1.01	1.01	.99	1.00

TABLE UNITS -- VEHICLE - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	51902.7	207160.4	.0	.0	259063.1
2	.0	92824.0	80862.9	78866.5	.0	.0	.0	60855.3	313408.7
3	31375.3	144541.2	317030.7	16470.1	87261.8	24449.3	.0	101946.2	723074.7
4	3717.2	19735.3	87617.5	19703.9	.0	.0	.0	21248.0	152021.9
5	10973.3	43045.9	45805.5	.0	.0	.0	.0	.0	99824.6
12	.0	94315.8	182856.2	40485.3	40291.5	232099.7	.0	25373.3	615421.8
14	.0	4173.5	29296.7	162737.1	81789.4	49253.1	99293.3	95343.1	521886.3
TOTAL	46065.9	398635.6	743469.3	318263.0	261245.5	512962.5	99293.3	304765.8	2684701.0

TABLE UNITS -- CAPACITY2 - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	54800.0	218200.0	.0	.0	273000.0
2	.0	102089.0	76062.0	89564.0	.0	.0	.0	65090.0	332805.0
3	30555.0	148999.0	319626.0	16022.0	89517.0	23259.0	.0	104992.0	732970.0
4	3489.0	18485.0	78649.0	16371.0	.0	.0	.0	20108.0	137102.0
5	11350.0	39862.0	40151.0	.0	.0	.0	.0	.0	91363.0
12	.0	83497.0	179206.0	40438.0	40024.0	225744.0	.0	25081.0	593990.0
14	.0	4498.0	30303.0	157506.0	69498.1	50218.0	98663.0	90293.0	500979.1
TOTAL	45394.0	397430.0	723997.0	319901.0	253839.1	517421.0	98663.0	305564.0	2662209.0

TABLE UNITS -- VOLUME/CAPACITY2

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.00	.00	.00	.00	.95	.95	.00	.00	.95
2	.00	.91	1.06	.88	.00	.00	.00	.93	.94
3	1.03	.97	.99	1.03	.97	1.05	.00	.97	.99
4	1.07	1.07	1.11	1.20	.00	.00	.00	1.06	1.11
5	.97	1.08	1.14	.00	.00	.00	.00	.00	1.09
12	.00	1.13	1.02	1.00	1.01	1.03	.00	1.01	1.04
14	.00	.93	.97	1.03	1.18	.98	1.01	1.06	1.04
TOTAL	1.01	1.00	1.03	.99	1.03	.99	1.01	1.00	1.01

DCCO / UAG
TRANPLAN SYSTEM
VERSION 5.0

REPORT HIGHWAY NETWORK SUMMARY
VMT AND V/C RATIO BY FUNC.CLASS. AND BY JURISDICTION FROM SDHPT
FOR LOADING OF EQUILIBRIUM

PAGE NO. 1
DATE 03AUG88
TIME 10:03:00

TABLE UNITS -- VEHICLE - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	51699.5	207317.6	.0	.0	259017.2
2	.0	93834.6	84906.0	86889.2	.0	.0	.0	63153.5	328783.4
3	31402.1	142808.0	326519.2	13733.6	85919.6	24311.8	.0	100683.7	725377.9
4	4076.6	17616.5	80551.2	15665.2	.0	.0	.0	15336.8	133246.3
5	9565.8	42942.4	45435.6	.0	.0	.0	.0	.0	97943.8
12	.0	93929.3	182177.0	40690.5	39716.9	234090.0	.0	25366.1	615969.8
14	.0	3760.3	28870.3	160114.2	81396.2	47708.7	95959.7	90863.6	508673.0
TOTAL	45044.5	394891.1	748459.4	317092.7	258732.3	513428.0	95959.7	295403.7	2669012.0

TABLE UNITS -- CAPACITY2 - MILES

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.0	.0	.0	.0	54800.0	218200.0	.0	.0	273000.0
2	.0	102089.0	76062.0	89564.0	.0	.0	.0	65090.0	332805.0
3	30555.0	148999.0	319626.0	16022.0	89517.0	23259.0	.0	104992.0	732970.0
4	3489.0	18485.0	78649.0	16371.0	.0	.0	.0	20108.0	137102.0
5	11350.0	39862.0	40151.0	.0	.0	.0	.0	.0	91363.0
12	.0	83497.0	179206.0	40438.0	40024.0	225744.0	.0	25081.0	593990.0
14	.0	4498.0	30303.0	157506.0	69498.1	50218.0	98663.0	90293.0	500979.1
TOTAL	45394.0	397430.0	723997.0	319901.0	253839.1	517421.0	98663.0	305564.0	2662209.0

TABLE UNITS -- VOLUME/CAPACITY2

FUN. CL. \ JURISD.	1	2	3	4	5	6	7	8	TOTAL
1	.00	.00	.00	.00	.94	.95	.00	.00	.95
2	.00	.92	1.12	.97	.00	.00	.00	.97	.99
3	1.03	.96	1.02	.86	.96	1.05	.00	.96	.99
4	1.17	.95	1.02	.96	.00	.00	.00	.76	.97
5	.84	1.08	1.13	.00	.00	.00	.00	.00	1.07
12	.00	1.12	1.02	1.01	.99	1.04	.00	1.01	1.04
14	.00	.84	.95	1.02	1.17	.95	.97	1.01	1.02
TOTAL	.99	.99	1.03	.99	1.02	.99	.97	.97	1.00

APPENDIX B

FORTRAN Program for Statistical Measures of Link Differences

This appendix presents a FORTRAN program developed for the statistical measure of link differences. In determining the statistical measures of link differences for the assignments using the five techniques, the counted volume for any given link was subtracted from the corresponding assigned volume. Five common statistical measures [mean difference (MD), standard deviation(SD), root-mean-square (RMS) error, percent RMS (PRMS), and percent SD (PSD)] were employed in the evaluation of link differences.

```
C*** THIS IS THE PROGRAMS FOR STATISTICAL MEASURES OF
C*** LINK DIFFERENCES IN COMPARISON OF ASSIGNMENT TECHNIQUES VS.
C*** GROUND COUNT USING A TOTAL OF 1686 LINKS EXCLUDING
C*** CENTROID CONNECTORS AND EXTERNAL CONNECTORS.
      INTEGER VOL(1686,6),MAN(5),MEAN(5),ISD(5),IRMS(5)
      REAL RPRMS(5),RIMS(5),RPSD(5)
C*** READ ZRERR01.OUT TABLE
      OPEN (5,FILE='ZRERR01.OUT',STATUS='OLD')
      DO 20 I = 1,1686
       READ (5,10) (VOL(I,J), J=1,6)
   10  FORMAT (16X,6I10)
   20 CONTINUE
C*** INITIATE COUNT MEAN(IMEAN), ASSIGNED VOL MEAN(MAN),
C*** MEAN DIFFERENCE(MEAN), MEAN SQUARE(RIMS)
      OPEN (6,FILE='ZREST01.OUT',STATUS='NEW')
       IMEAN = 0
      DO 30 J = 1,5
       MAN(J) = 0
       MEAN(J) = 0
       RIMS(J) = 0.
   30 CONTINUE
C*** CALCULATIONS i
      DO 60 I = 1,1686
       IMEAN = VOL(I,1)+IMEAN
      DO 40 J = 2,6
       MAN(J-1) = VOL(I,J)+MAN(J-1)
       MEAN(J-1) = (VOL(I,J)-VOL(I,1))+MEAN(J-1)
       RIMS(J-1) = (VOL(I,J)-VOL(I,1))**2 + RIMS(J-1)
   40 CONTINUE
   60 CONTINUE
       RMEAN = IMEAN/1686.
C*** CALCULATIONS ii
      DO 70 J = 1,5
       MAN(J) = MAN(J)/1686.+0.5
       MEAN(J) = MEAN(J)/1686
       RIMS(J) = RIMS(J)/731.
       ISD(J) = SQRT(RIMS(J)-(MEAN(J))**2) + 0.5
       IRMS(J) = SQRT(RIMS(J)) + 0.5
       RPRMS(J) = 100*(IRMS(J)/RMEAN)
       RPSD(J) = 100*(ISD(J)/RMEAN)
   70 CONTINUE
      DO 90 J = 1,5
       WRITE (6,85) MAN(J),MEAN(J),ISD(J),IRMS(J),RPRMS(J),RPSD(J)
   85  FORMAT (10X,4I10,2F10.1)
   90 CONTINUE
      STOP
      END
```

APPENDIX C

FORTRAN Program for Chi-Square Statistical Test

This appendix presents a FORTRAN program developed for the statistical test of link differences. The Chi-Square test was employed to determine if any of the differences between assigned and counted volumes are statistically significant, and/or to compare if any different results among the five assignment techniques are statistically significant. Also, the calculated Chi-Square values were used to compare results based on the different traffic assignment techniques.

```
C*** THIS IS CALCULATION PROGRAM TO GET # OF LINKS IN
C*** VOLUME GROUPS IN COMPARISON OF ASSIGNMENT TECHNIQUES
C*** VS. GROUND COUNT USING A TOTAL OF 1686 LINKS
C*** EXCLUDING CENTROID CONNECTORS AND EXTERNAL CONNECTORS.
      INTEGER VOL(1686,6), A(20,6)
      REAL CHI(21,6)
C*** READ ZRERR01.OUT TABLE
      OPEN (5,FILE='ZRERR01.OUT',STATUS='OLD')
      DO 20 I = 1,1686
       READ (5,10) (VOL(I,J), J=1,6)
   10  FORMAT (16X,6I10)
   20 CONTINUE
      OPEN (6,FILE='ZRECH01.OUT',STATUS='NEW')
      DO 90 J = 1,6
      DO 85 K=1,20
       A(K,J)=0
   85 CONTINUE
      DO 80 I = 1,1686
       IF (VOL(I,J).LE.1000) THEN
        A(1,J)=A(1,J)+1
       ELSE IF (VOL(I,J).LE.2000) THEN
        A(2,J)=A(2,J)+1
       ELSE IF (VOL(I,J).LE.3000) THEN
        A(3,J)=A(3,J)+1
       ELSE IF (VOL(I,J).LE.4000) THEN
        A(4,J)=A(4,J)+1
       ELSE IF (VOL(I,J).LE.5000) THEN
        A(5,J)=A(5,J)+1
       ELSE IF (VOL(I,J).LE.6000) THEN
        A(6,J)=A(6,J)+1
       ELSE IF (VOL(I,J).LE.7000) THEN
        A(7,J)=A(7,J)+1
       ELSE IF (VOL(I,J).LE.8000) THEN
        A(8,J)=A(8,J)+1
       ELSE IF (VOL(I,J).LE.9000) THEN
        A(9,J)=A(9,J)+1
       ELSE IF (VOL(I,J).LE.10000) THEN
        A(10,J)=A(10,J)+1
       ELSE IF (VOL(I,J).LE.11000) THEN
        A(11,J)=A(11,J)+1
       ELSE IF (VOL(I,J).LE.12000) THEN
        A(12,J)=A(12,J)+1
       ELSE IF (VOL(I,J).LE.13000) THEN
        A(13,J)=A(13,J)+1
       ELSE IF (VOL(I,J).LE.14000) THEN
        A(14,J)=A(14,J)+1
       ELSE IF (VOL(I,J).LE.15000) THEN
        A(15,J)=A(15,J)+1
```