□ 論　文 □

교통배분의 민감도 분석에 관한 연구

A Sensitivity Analysis of Traffic Assignment

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目　次

국 문 요 약

본 연구에서는 다른 기종점 통행표(Trip Matrices)들을 같은 교통망(Network)에 배정하였을 때 교통분배 결과의 차이점들을 분석하고 교통분배의 민감도를 비교하였다. 전통적인 4단계 교통수요 추정에 의해서 산출된 교통배분을 비교의 기본자료로 이용했다. 또한 본 연구에서는 교통배분의 결과를 평가하기 위해 주로 사용하는 측정효과들과 교통배분의 기법들(Traffic Assignment Techniques)의 민감도도 연구조사하였다.

본 연구를 통하여 총교통량(Total Trips)과 통행길이빈도(Trip Length Frequency)제약에 의해 임의로 선출된 기종점 통행표를 이용한 교통배분의 결과는 전통적인 4단계 교통수요 측정에 의해 산출된 교통배분 및 조사교통량(Counted Traffic Volumes)에 매우 유사한 결과가 나왔다. 결론적으로 존별 통행발생량에서의 오차는 교통배분의 본성적인 집계특성(Aggregative Nature)에 의하여 그 심각성이 감소되는 경향이 있다. 이것은 즉 앞단계(Trip Generation and Distribution Phases)에서 전통적으로 요구되어지는 정밀도가 없어도 적절한 교통배분기법을 사용함으로써 좋은 결과를 산출할 수 있다는 것을 암시한다.

I. INTRODUCTION

Traffic assignment is a process used for estimating traffic volumes on a coded transportation system using the travel-demand information developed in provious modeling steps. Inputs to the traditional traffic assignment process include a coded network which is an abstract representation of a transportation network and a trip table which represents the number of trips between each zone pair.

This is research was undertaken to investigate differences in the assignment results when different trip matrices were assigned to the same coded network. In addition to investigating the sensitivity of the assignment results to diffenent trip matrices, the resarch also evaluated the sensitivity of the assignment results using different assignment techniques.

II. LITERATURE REVIEW

Considerable research has been conducted in the development of efficient algorithms for traffic assignment during the past 40 years. However, little research been directed toward testing the accuracy of traffic assignments.

In 1975, a sensitivity evaluation of traffic assignment by Buechler, Stover, and Benson (1) investigated the effects of different trip matrices on traffic assignment results. They also evaluated the sensitivity of the measures commonly used to assess assignment results. The results of the analyses indicated that a stochastic trip matrix constrained to the total number of trips and the desired mean trip length produced acceptable traffic assignment results.

Dowling and May (2) evaluated three different techniques (Proportional, LINKOD model, and Regional Approach techniques) for estimating or forecasting the vehicular origin-destination patterns. When the three diffenent OD tables were assigned to the street network, much of the difference among the OD tables was masked by the assignment process.

The Bureau of Public Roads (3) suggested that the observed and the calculated trip length frequency (TLF) should exhibit : the shape and position of both curves should be relatively close to one another, and the difference botween the average trip lengths should be within 3 percent. Other research by Stover, Pearson, and Benson (4) produced a technique to theoretically estimate the TLF distribution for and an urban area. Further research by Stover, Benson, and Foster (5) indicates that if a home interview study is to be undertaken, acceptable results can be obtained with as few as 400 to 800 dwlling unit interviews when using home-based work, home-based none-work, and non-home based trip purposes.

The publication, "Traffic Assignment," produced by the Federal Highway Administration in 1973 (6), identified the following five statistical measures which were employed to compare traffic assignment results with ground counts : total volumes across some aggregation such as total study area, screenlines, or cutlines : total vehicle-miles of travel (VMT) : total weighted error : root-mean-square (RMS) errors : and a graphic comparison.

Efficient algorithms that produce equilibrium in the assignment of traffic to a network have been developed more recently. It is common to refer to assigned trips that rigorously satisfy Wardrop's first principle (7) as equilibrium flows. However, there is very little published material available on the application of equilibrium assignment methods in actual practice. LeBlanc et al. (8) presented a solution technique for large scale network equilibrium assignment and related flow problems with nonlinear costs. Eash, Janson, and Boyce (9) remarked that the use of equilibrium assignment to produce 24−hour assignments may be inappropriate in that only the peak periods have truly congested flow : in other words, all−or−nothing assignment may be sufficient for off−peak periods.

Ⅲ. RESEARCH PROBLEM

The focus of this research was to study the sensitivity of the traffic assignment to different trip matrices generated from various constraints. If there is no significant difference between assigned volumes using different trip matrices, differences observed at the zonal level and zonal interchange level are masked by the assignment process. This would indicate that the traffic assignment is not highly sensitive to the trip matrix.

The fully modeled trip matrix developed in the traditional method was selected and used as the standard for comparison in the analyses. The trip distribution were performed to develop fully modeled results for each trip purpose : the resulting matrices by each trip purpose were then merged to obtain an assignment matrix. The research hypotheses were as follows :

1. The assignment using the fully modeled trip matrix is more accurate than any one of the assignment results based on different trip matrices generated from various constraints.
2. The equilibrium traffic assignment technique provides better results than the all−or−nothing, "stochastic" multipath, or incremental techniques when using various trip matrices.

TRANPLAN/NEDS, microcomputer package, was used for this study. The study did not attempt to evaluate the capabilities, features, or qualities of the software package. Several of the available software packages have been analyzed elsewhere(10−12).

Ⅳ. RESEARCH METHODOLOGY

A "better−worse" approach of one input constraint at a time was used in developing data matrices for analyzing the sensitivity of the measures of accuracy of traffic assignment results. Four different stochastic matrices and the fully modeled trip matrix were initially generated for the internal trip purposes. These were used to generate five different traffic assignments using the all−or−nothing technique on the same network. 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.

The two "best" of the four stochastic trip matrices were selected based on the results of the macro-lovel measures. The external-local and external-through trips were then merged to the two selected matrices and the fully modeled trip matrix for further analyses. These were used to generate three different traffic assignments using the all-or-nothing technique on one network.

In order to ,evaluate the macro-lovel measures statistically, a nonparametric statistical test was applied to determine if the results from the two stochastic matrices were significantly different from the results using the fully modeled trip matrix. The Small-Sample Wil coxon Signed-Rank test was used to detect differences between the total volumes for each screenline, cutline, and travel route. The fully modeled and stochastic matrices were compared to ground conts and the stochastic matrices were compared to the fully modeled matrix. In addition to the all-or-nothing (AON) assignment, "stochastic" multipath (STO) assignment, incremental capacity-restraing (INC) assignment, and equilibrium (EQU) assignment wer applied to the two stochastic matrices and the fully modeled trip matrix.

V. DATA

The existing 1985 network for Bryan/College Station(B/CS), Texas, was selected as the test bed. This well-detailed and coded network consisted of 241 internal zones, 28 dummy zones, 16 external stations, 688 nodes, and 1740 directional(one-way)links(including the links to external stations but excluding centroid connectors). There are a total of 454, 884 vehicular trip ends in the study area : 394, 729 are internal trips and 60, 155 are external trips.

1. Data Generation for Internal Trip Matrix

The "better-worse" approach of one input constraint at a time was used in developing data matrices for analyzing the sensitivity of the measures of accuracy of traffic assignment results. The "better-worse" gradient hypothesized that the desirable assignment would result from a stochastic trip matrix subjected to the following selected constraings :

- Total internal trips
- Row and column totals of the trip table
- Desired trip length frequency
- Desired trip ends at each external station

The following trip matrices were assigned to the B/CS network and the results compared :

- Matrix 1 (M1)-A stochastic trip matrix constrained by using the total internal trips divided by the total possible interchanges (cells). Thus, each cell in the matrix contained the same number of trips.
- Matrix 2 (M2)-A stochastic trip matrix constrained only to the total internal trips and obtained using a uniform random number generator.
- Matrix 3 (M3)-A stochastic trip matrix constrained to the row and column totals of the trip table (zonal trip ends)using the following proportional technique and procedures :

  $T_{ij} = T_i \times T_j/TT$

  where : T_{ij}=number of trips from zone i to zone j

T_i =total trips produced in zone i (row tatal)

T_j =total trips attracted to zone j (column tatal)

TT=total internal trips(394, 729 trips)

- Matrix 4 (Ms)−A stochastic trip matrix constrained to the total internal trips by trip purposes as well as the desired trip length frequency (TLF) for the urban area. The imposition of the TLF constraing was expected to produce a matrix which would yield better assignment results than the provious stochastic trip matrices.
- Matrix 5 (M5)−A Fully Modeled Matrix resulting from trip generation and distribution for the internal zones using the four internal trip purposes. This trip matrix was used as the standard for comparison of Matrices 1, 2, 3 and 4.

2. Trip Matrix Comparisons

In outlining the research, it was decided that traffic assignments would be made only in the stochastic trip matrices (M1, M2, M3 and M4) were different from the Fully Modeled Matrix (M5). Figure 1 shows the distribution of trip productions resulting with the five trip matrices.

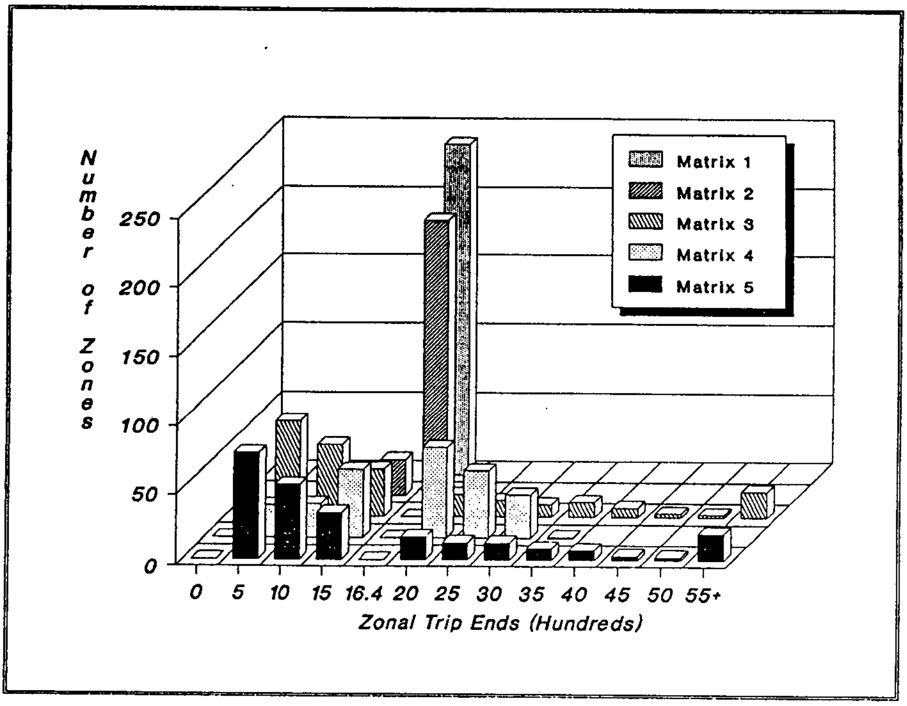

Figure 1. Comparisons of Trip Production Distributions

As expected, the TLF constraing (Matrix 4) resulted in a considerable improvement in the distribution of zonal trip productions. Inspection of Figure 1 shows that Matrices 3 and 5 have almost identical distributions of trip productions. This is, of course, due to the fact that Matrix 3 is constrained to the same row and column totals as Matrix 5. The constraints of the row and column totals and the trip length frequency were obviously effective. However, this does not mean the two matrices are the same on a cell-by-cell basis. Matrices 3 and 4 were compared with Matrix 5 on a cell-by-cell bssis because the frequency distriutions of zonal interchange (cell) volumes were similar. It was concluded that there is a substantial absolute difference between Matrix 4 and Matrix 5 and that the absolute difference between Matrix 3 and Matrix 5 is of practical significance.

The common statistical measures were employed in the evaluation of trip table differences on a cell-by-cell basis (see Table 1). As indicated, there is no difference between standard deviation and root-mean-square because there are no differences in mean traffic volume among the trip matrices. Consequently, it was found that there was a large difference between Matrices 1 and 2 and the Fully Modeled Matrix 5. Matrix 4 shows very significant differences in comparison to valuse of the four statistical measures from Matrix 5. Matrix 3 produced no significant difference from Matrix 5.

Table 1. Summary Of Statistical Comparisons

	Standard Deviatioin (SD)	Root-Mean-Square (RMS)	Percent RMS (PRMS)	Sum of Square (SUMSQ)
M1 vs. M5	23.92	23.9	351.92	33,242,337
M2 vs. M5	23.79	23.8	349.94	32,869,235
M3 vs. M5	11.57	11.6	170.25	7,779,687
M4 vs. M5	23.26	23.3	342.17	31,425,166

3. Comparison of Trip Length Frequency Distributions

The "calculated" trip length frequency (TLF)l distribution was compared with the "desired" TLF distribution used in the Fully Modeled Matrix 6. Figure 2 illustrates the distribution of TLF for the stochastic matrices compared to the distribution for the Fully Modeled Matrix 5. It should be recalled that of the stochastic matrices, only Matrix 4 was generated using the constraint of the desired trip length frequency. Therefore, the TLF distribution for Matrix 4 should be the smae as the distribution for Matrix 5. The constraint of the row and column totals of the trip table used for generating Matrix 3 shows some improvement over Matrices 1 and 2. However, the distribution of Matrix 3 appears to be somewhat skewed to the right as compared to the distribution for Matrix 5.

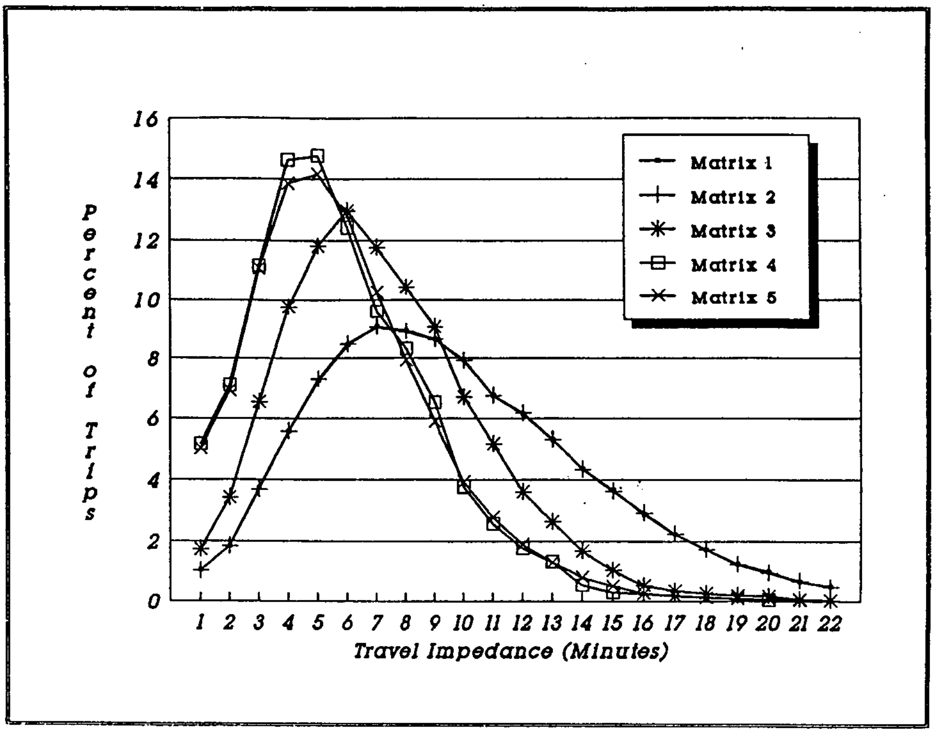

Figure 2. Comparisons of Trip Length Frequency Distributions

Ⅵ. MACRO-LEVEL ANALYSES

Five measures of assignment accuracy at the macro-level were utilized in evaluating the all-or-nothing assignment of the four stochastic matrices compared to the Fully Modeled Internal Tip Matrix. The assigned volumes converted to a percont difference such that a + value indicated an overassignment as compared to Matrix 5. Assigned Macro-level volumes were considered acceptable if they were within a +20 percent difference from Matix 5.

Four screenlines and eleven cutlines were established on the Bryan/Callege Station network. Table 2 indicates the percent differences for the screenlines and the cutlines. The measures of the screenlines and cutlines resulted in significant differences in the total assigned volumes from Matrices 1 and 2. Matrix 3 produced somewhat better cutlines comparisons than Matrix 4 compared to Matrix 5.

Six differen travel routes were selected for the analysis of major travel routes. Tavle 3 shows the average link volumes of the Fully Modeled Matrix 5 and the percent differences. All six travel routes for Matrix 3 were overassigned but not as much as Matrices 1 and 2. Three of the six travel routes for Matrix 4 were overassigned and three were underassigned. The average difference (−11.38 percent)was considered acceptable.

Table 2. Percent Differences In Screenline And Cutline Volumes In Comparison To Fully Modeled Matrix 5

	M5	percent Difference			
Screenlines/Cutlines	Volumes	M1	M2	M3	M4
SL1 (N−E)	148310	30.86	30.44	23.61	−11.83*
SL2 (E−W/S)	27970	97.93	96.96	17.09*	−42.12
SL3 (E−W)	117059	75.28	75.60	46.56	8.34*
SL4 (E−W/N)	17989	409.37	409.46	15.79*	112.97
Average Differences		153.36	153.12	25.76	16.84*
CL1 (A−A)	3013	621.08	625.62	11.05*	219.42
CL2 (B−B)	73091	−8.80*	−9.17*	56.58	−36.56
CL3 (C−C)	34212	−22.49	−22.84	31.73	−58.55
CL4 (D−D)	23712	77.34	79.45	22.53	58.20
CL5 (E−E)	36465	77.11	76.67	50.49	47.90
CL6 (F−F)	24963	−50.27	−50.39	−11.63*	−54.08
CL7 (G−G)	17977	157.99	157.92	12.75*	77.56
CL8 (H−H)	15471	109.59	110.43	40.56	14.32*
CL9 (I−I)	30767	−18.60	−19.40*	34.11	−51.01
CL10 (J−J)	11529	120.34	114.49	21.68	69.23
CL11 (K−K)	19548	60.64	62.28	6.11*	89.67
Average Differences		102.10	102.28	25.09	34.19
AD (excluding CL1)		50.29	49.95	26.49	15.67*

Note : * denotes acceptable values.

Table 3. Percent Differences In Travle Route Volumes In Comparison To Fully Modeled Matrix 5

Travel Routes	Mean Volume	M1	M2	M3	M4
TR1 (Hwy 21)	7595	199.17	198.45	8.72*	54.67
TR2 (Hwy 60)	13960	−28.45	−28.94	27.93	−43.62
TR3 (Tx Ave)	28949	17.81*	17.51*	51.06	−22.45
TR4 (FM 2818)	61.9	237.87	240.74	35.55	01.08*
TR5 (Hwy 30)	8767	−17.31*	−16.88*	29.40	−57.42
TR6 (Hwy 6)	6252	239.70	239.94	64.35	−9.55*
Average Percent Difference		108.13	108.47	36.17	−11.38*
Standard Deviation		130.37	130.95	19.41	40.27

Note : * denotes acceptable travel route.

Table 4 gives a summary of the ratio of assigned VMT in comparison to Matrix 5 for al links in the network based on the link speed and the capacity group. The difference in Matrix 3 indicated much less than Matrices 1 and 2. However, it was obvious that the VMT ratio for Matrix 4 (1.0) indicated the same VTM as Matrix 5 since Matrix 4 was basically a function of the zonal structure and the trip length frequency constraint which simply assured the desird number of vehicle–miles (or vehicle–hours) of travel on the network. While there is a significant difference in Matrix 3 compared to the Fully Modeled Matrix 5, the assignment for matrix 4 has no significant difference.

Finally, Matrices 3 and 4 were determined as the two "best" matrices from the four stochastic matrices and selected for further anslyses. Figure 3 shows the summary/conclusions of the sensitivity of the traffic assignment to the four stochastic matrices generated from various constraints.

Table 4. Vehicle–Miles of Travel (VMT) Ratio In comparison To Fully Modeled Matrix 5

Speed	Capacity	VMT for M5	M1	M2	M3	M4
60	43900	118448.0	3.2	3.2	1.7	0.9*
55	9100	7803.0	6.0	6.0	1.1*	1.3
50	8100	90753.8	3.6	3.6	1.3	1.3
50	5000	79001.8	4.9	5.0	1.1*	1.7
45	12750	288945.2	1.1	1.1	1.5	0.7
40	7400	310550.4	1.1	1.1	1.3	0.9*
35	4150	90566.1	2.1	2.1	1.2*	1.4
45	3900	59627.1	1.4	1.4	1.1*	0.9*
30	3900	115323.7	1.1	1.1	1.1*	0.9
Total VTM		1161019.0	1.9	1.9	1.3	1.0*

Note : * denotes acceptable VMT ratio.

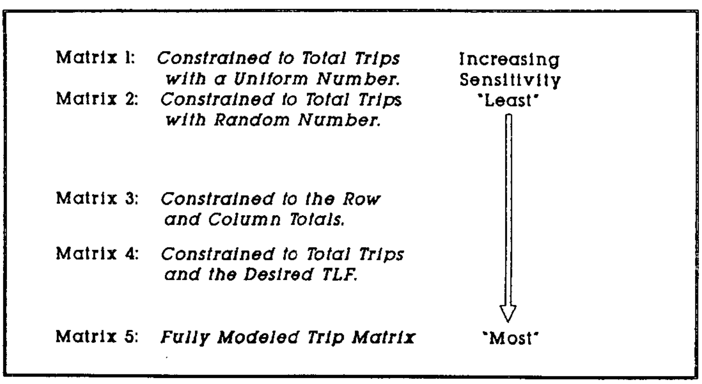

Figure 3. Sensitivity of Assignment Results Using Macro–Level Measures

The two "best" matrices of the four trip matrices were selected based on the results of the macro–level measures. The external–local and external–through trips were than merged to the two selected matrices and the fully modeled trip matrix for further analyses. These were used to generate three different traffic assignments using the all–or–nothing technique on one network. The following three matrices were generated :

- Matrix 6(M6)–A stochastic trip matrix using matrix 3 merged with the external–local and external–through trip matrix.
- Matrix 7 (M7)–A stochastic trip matrix using matrix 4 merged with the external–local and external–through trip matrix.
- Matrix 8 (M8, Fully Modeled Total Trip Matrix)–A matrix resulting from trip generation and distribution for the internal and external zones. The fully Modeled Trip Matrix developed in the traditional method was used as the standard for comparison with the Matrices 6 and 7 in the analyses.

A nonparametric statistical test wsa applied to determine : (1) if the total assigned volumes by Matrices 6 or 7 are significantly different from Matrix 8, and (2) if the total assigned volumes by Matrix 8 are more accurate than any one of two selected stochastic matrices compared to the ground counted volumes. A limited number of ground conts (134 links with ground conted volumes, 15.4 percent of total links) was available for the network. Volumes were calculated for 232 links not having a ground count record using the count data on either side these links.

The Small–Sample Wilcoxon Signed–Rank test was used as a two–tailed test to detect differences by the total volumes of each scerenline and cutline and by VTM of each travel route. It was concluded that the distributions of the total assigned volumes for Matrix 6 are different from the volumes for Matrix 8. The assignment of Matrix 6 was overassigned with 20 of the 21 measures having assigned valuse exceeding about 30 percent of the assigned volumes of Matrix 8. However, the distributions of the total assigned volumes for Matrix 7 and Matrix 8 could be the same.

The next series of comparisons using the Small–Sample Wilcoxon Signed–Rank Test were of the differences bdtween the counted volumes and each of the all–or–nothing assignment results from the three matrices (Matrices 6, 7, and 8). It was concluded that the distributions of the total assigned volumes for total assigned volumes for Matrices 7 and 8 could be equal to the ground conted volumes at a 90 percent level of confidence.

VII. MICRO–LEVEL ANALYSES

The all–or–nothing technique was used to evaluate the sensitivity of the traffic assignment to internal trip matrices. In addition to the all–or–nothing (AON) assignment, "stochastic" multipath (STO) assignment, incremental capacity-restraint (INC) assignment, and equilibrium (EQU) assignment accuracy was then evaluated using the micro–level measures of assignment accuracy. The micro–level measures of asssignment accuracy consisted of several tests that utilized the link–by–link differences between ground counts and jthe assigned volumes for analysis from various perspectives. For the micro-level measures of the link-by-link comparisons, a total of 732 directional links (42.1 percent from the total 1740 links)was selected.

The differences between assigned and counted link volumes were tablated for each link by absolute error ranges and by percent error ranges (see Table 5). Generally, the values in Table 5 increased silghtly from the all-or-nothing (AON) to the equilibrium (EQU) assignment techniques. The values for the assignment of the Fully Modeled Matrix 8 indicated the best results compared to ground counts. Traffic assignment was found more sensitive to the constraint of the row and column totals than the TLF constraint on the distribution of link differences by the error ranges.

Table 5. Distribution Of Differences By Error Ranges(Values in Percent)

Matrix	Assign	Absolute Error (vpd)				Percent Error (%)				
		±500	±1000	±2000	±2000+	±10	±25	±50	±100	±100+
M6	AON	35.5	50.7	66.4	100	22.3	39.9	62.0	88.5	100
M6	STO	35.5	50.4	68.3	100	22.8	43.4	64.3	87.8	100
M6	INC	36.1	50.3	66.1	100	28.1	49.3	69.1	84.3	100
M6	EQU	36.5	53.7	70.8	100	27.2	46.0	69.7	90.2	100
M7	AON	25.3	40.7	62.0	100	16.5	36.5	63.9	88.7	100
M7	STO	26.1	41.8	63.5	100	17.5	35.7	62.4	89.3	100
M7	INC	21.7	39.3	66.1	100	16.7	37.4	64.9	86.6	100
M7	EQU	27.9	44.4	68.0	100	21.6	42.5	69.3	89.3	100
M8	AON	37.3	55.6	73.8	100	26.0	47.1	73.9	96.9	100
M8	STO	37.3	56.6	73.6	100	27.6	48.8	75.8	96.2	100
M8	INC	39.9	57.7	79.4	100	30.2	56.1	80.5	92.1	100
M8	EQU	42.9	59.8	78.6	100	30.9	54.0	77.3	96.0	100

The five statistical measures (as defined earlier) were employed in the evaluation of link differences. Table 6 summarizes the results of the statistical measures of link differences of the three matrices compared to ground counts using the four techniques. The results of Matrix 7 and Matrix 8 appear to be similar, with the assignment of the Fully Modeled Matrix 8 judged to be slightly better. The assignment of Matrix 6 had obviously the largest link differences. Also, it was concluded that there is no significnt difference between the all-or-nothing technique and the stochastic technique in this B/CS network. It was noticed that the Fully Modeled Matrix 8 assignment using the incremental technique produced the smallest percent RMS error, and the assignment of Matrix 7 using the equilibrium technique resulted in the second smallest. The incrementsl assignments represented the best technique to affect the measures of the link differences by percent RMS error.

Table 6. Statistical Measures Of Link Differences

ASSIGNMENT	MATRIX	VOLUME	MD	SD	RMS	PRMS	RSD
ALL−OR−	M6	7965	2411	6341	6784	122.2	114.2
NOTHING	M7	5615	61	2890	2891	52.1	52.0*
(AON)	M8	6122	568	2987	3037	54.7	53.7*
STOCHASTIC	M6	7837	2282	5778	6212	119.9	104.0
(STO)	M7	5604	50	2958	2959	53.3	53.3*
	M8	6056	502	2737	2783	50.1	49.3*
INCREMEN-	M6	6408	854	2836	2962	53.3	51.1*
TAL	M7	4915	-638	2656	2731	49.2	47.8*
(INC)	M8	5096	-457	2300	2345	42.2	41.7*
EQUILIBRIUM	M6	6923	1369	3757	3998	72.0	67.6
(EQU)	M7	5012	-431	2434	2471	44.5	43.8*
	M8	5025	-528	2707	2758	49.7	48.7*

Note : * denotes acceptable percent difference.

The degree of goodness of the results needs to be established by relating the stochastic matrix assignments to several modeled assignments. The values of the percent standard deviation (PSD) from traffic assignments conducted in various cities were used as the acceptable ranges from 30.9 to 55.3 percent. The assignments for Matrix 7 have relatively largy values of the PSd compared to the values of the ten selected cities : however, all are within the range as well as the four assignments for the Fully Modeled Matrix 8. Only one assignment (INC) for Matrix 6 is within the acceptable range of the PSD. The nine values of the 12 PDS of the B/CS network were within acceptable ranges shown in Table. 6.

The 12 (3 matrices x 4 techniques) Chi−Square (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 calculated (X^2) values for the three matrices and the four assignment techniques (a set of 12 values) are tabulated in Table 7. Since the computed values of X^2 for all of the 12 assignments are greater than the tabulated critical value(25.9844), 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. Also, nono of the four assignment techniques was distributed the same as ground counts at the 0.10 level of significance.

The values for the assignments of Matrix 6 indicated the poorest results compared to ground counts. The values for the assignment of the Fully Modeled Matrix 8 were somewhat better than the results of Matrix 7. It should be noticed that the computed X^2 values for the assignment of Matrix 7 using the all−or−nothing and equilibrium techniques were very similar to the values for the assignment of the Fully Modeled Matrix 8 using those techniques. Based on the Chi−Square test using the distribution of the selected links by the volume group, traffic assignment was much less sensitive to the constraint of the row and column total than the TLF constraint.

Table 7. Summary Of Calculated Chi−Square Values

ASSIGNMENTS	MATRIX 6	MATRIX 7	MATRIX 8
ALL−OR−NOT. (AON)	877.37	255.96	258.68
STOCHASTIC (STO)	712.24	318.71	205.36
INCREMENTAL (INC)	203.50	299.88	81.00
EQUILIBRIUM (EQU)	318.78	147.45	147.04

The Kruskal−Wallis test was used to determine if there was a signifi cant difference between assignment results for the three matrices. The test was performed for each of the four different traffic assignment techniques.

Although the test results showed that the distributions among the three matrices were statically different at the 0.10 level of significance, the assignments of the Fully Modeled Matrix resulted in the closest agreement with the counted volumes. It was concluded that Matrix 6 is overassigned with less dispersion than Matrix 7, and that the Matrix 6 result was better than Matrix 7 using the 119 selected links. Unlike the results of the previous measures, the all−or−nothing assignment technique provided the best comparisons to ground counts : the incremental assignments produced the poorest results.

The Large−Sample Wilcoxon Signed−Rank test was used to compare if any different results between one of the three matrices and the counted volumes are statistically significant for the four techniques. The five values of the 12 calculated Z values were less than the critical value at the 0.10 lkevel of significance. Thus, it was concluded that the distributions of the five assignments were essentialy the smae as the distribution of the counted volumes statistically. These five assignments are as follows : the all−or−nothing assignments for Matrices 6 and 7, the "stochastic" mulltipath assignments for Matrices 6 and 87, and the equilibrium assignment for Matrix 8. As concluded using the previous Kruskal−Wallis test, the all−or−nothing assignments produced the best results in comparison to the counted volumes, while the incremental (INC) assignments produced the poorest results. Generally, the assignments of the Fully Modeled Matrix 8 had the best dstributions compared to the counted volumes. Based on the Large−Sample Wilcoxon Signed−Rank test, it was concluded that traffic assignment is more sensitive to the constraint of the desired TLF than the constraint of the row and column totals.

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 using the four assignment techniques. Unlike the results of macro−level analyses, the micro−level measures were found to yield the various results. Table 8 summarizes the results of the micro−level anslyses using the relative values by rankings.

Table 8. Summary Of Micro−Level Measures By Rankings

MEASURES	Matrix 6				Matrix 7				Matrix 8			
	AON	STO	INC	EQU	AON	STO	INC	EQU	AON	STO	INC	EQU
Absolute Differences	5	6	6	8	1	3	3	4	9	10	11	12
Percent Differences	4	6	7	7	2	2	2	6	9	10	11	12
Average Differences	6	6	7	6	3	5	3	6	8	8	9	11
Mean Differences	1	2	4	3	11	12	5	10	6	8	9	7
Standard Deviation	1	2	7	3	6	5	10	11	4	8	12	9
RMS Errors	1	2	5	3	7	6	10	11	4	8	12	9
Chi−Square Test	1	2	9	3	7	4	5	10	6	8	12	11
Kruskal−Wallis Test	11	5	2	8	10	4	1	7	12	6	3	9
Wilcoxon Test	10	12	1	2	11	6	4	7	3	8	5	9
Sum of Rankings	40	43	48	43	58	47	43	72	61	74	84	89

Note : The higher rank indicates the more sensitive : that is, rank 1 is the least sensitive, while rank 12 is the most.

Figure 4 is a graphic presentation of the total rankings in Table 8 which indicates the higher ranks in the assignment of Matrix 8 than others from the results of all nine micro−level measures. Inspection of the results for the Fully Modeled Matrix 8 in Figure 4 showed constant improvements from the all−or−nothing assignment technique to the equilibrium technique. Also, Matrix 6 indicated slight improvement in results except for the equilibrium technique which resulted in s ranking about the same as for the "stochastic" multipath technique. The results of the micro−level measures for Matrix 7 represented the constant decreasing ranks from the all−or−nothing to the incremental, but dramatic improvement was observed with the equilibrium.

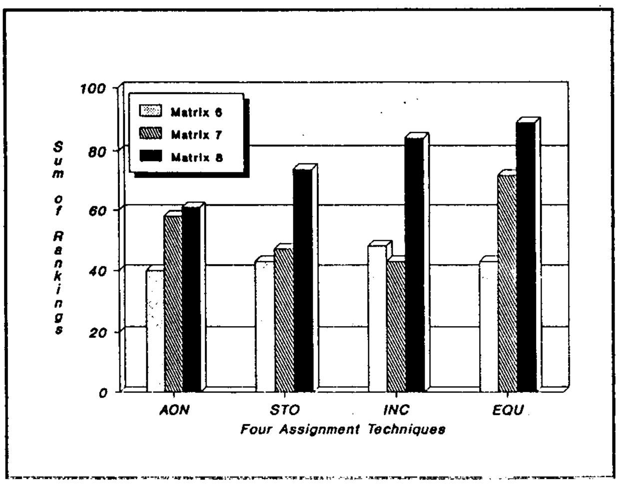

Figure 4. Summary of Micro−Level Measures by Sum of Rankings.

Ⅶ. FINDINGS AND CONCLUSIONS

Table 9 presents an overall qualitative evaluation of the sensitivity of traffic assignment to the trip matrices and the assignment techniques. The findings of this research are as follows :

Table 9. Summary Of Sensitivity Analysis

MEASURES OF ACCURACY	Matrix 6				Matrix 7				Matrix 8			
	AON	STO	INC	EQU	AON	STO	INC	EQU	AON	STO	INC	EQU
Screenlines	**	–	–	–	*	–	–	–	**	–	–	–
Cutlines	*	–	–	–	*	–	–	–	*	–	–	–
Travel Routes	n	–	–	–	**	–	–	–	**	–	–	–
VMT	n	–	–	–	**	–	–	–	**	–	–	–
Total Macro–Level	*	–	–	–	**	–	–	–	**	–	–	–
Absolute Error	**	**	**	**	*	*	*	*	**	**	**	**
Percent Error	*	*	**	**	*	*	*	**	**	**	**	**
Volume Group	*	*	*	*	*	*	**	*	**	**	**	**
Total Error Ranges	*	*	**	**	*	*	*	*	**	**	**	**
Mean Difference	n	n	*	n	*	*	**	**	*	*	*	*
Standard Deviation	n	n	**	*	*	*	**	**	*	**	**	**
RMS Error	n	n	*	*	*	*	**	**	*	*	**	**
Total Statistics	n	n	*	*	*	*	**	**	*	*	**	**
Chi–Square	n	n	*	*	*	*	*	**	*	**	**	**
Kruskal–Wallis	**	*	n	*	n	n	n	n	**	**	**	**
Wilcoxon	**	**	n	n	**	*	*	**	*	*	*	**
Total Tests	**	*	n	*	*	*	*	**	*	**	**	**

Note : –=Not Available, n=Not Sensitive, *=Little Sensitivity, and **=Very Sensitivity.

1. In general, all measures of assignment accuracy indicated that the Fully Modeled Trip Matrix (Matrix 8) produced the best results compared to ground count. The assignments of Matrix 6 (row and column totals constraint) and Matrix 7(trip length frequency constraint) gave similar results with the assignment of Matrix 7 usually being slightly better. Traffic assignment is more sensitive to the TLF constraint than the constraint of the row and column totals.
2. However, a matrix constrained to the row and column totals produces fair assignment results in a small urban area because the effect of resistance to travel in such an urban area is limited. The corollary is that traffic assignment results in a small urban area are not very sensitive to the trip length frequency. This suggests that less concern needs to be given to the determination of

the trip length frequency and gravity model calibration in small and medium-size urban areas than in large urban areas.

3. Application of the constraints of total trips and a desired TLF resulted in assigned volumes which very closely match the assigned volumes from Fully Modeled Trip Matrix and/or counted volumes. This will be the case even though the distribution of zonal trip ends is fairly uniform (and unrealistically)distributed. Therefore, the assignment results are not highly sensitive to the spatial distribution of trip ends.
4. The differences in the assinment results were not nearly as great as the differences in the trip matrices. This indicates that the assignment process masks substantial differences in the trip tables due to the fact that the number of links is much smaller than the number of centroid pairs(cells in a trip matrix). In other words, the assignment process, due to its aggregative nature, overcomes inadequacies from the preceding modeling phases(i.e., trip generation and trip distribution phases).
5. The incremental and the equilibrium assignments produces a slight improvement over the all-or-nothing and the "stochastic" multipath assignments. However, the difference in results was not significant enough to warrant the extra cost of developing the link capacity data needed for the incremental and the equilibrium assignments.

Ⅸ. RECOMMENDATIONS

Although it is difficult to establish the desired levels of accuracy for which all practitioners should strive, it is recommended that desirable accuracy levels could be established by each analyst relative to the use to be made of the assignment results. Several measures should be calculated and analyzed in combination with full awareness of the strengths and weaknesses of each, becsuse no single value adequately indicates the accuracy of an assignment. Also, any statistical tests should not be used directly(and/or solely) to evaluate and determine the assignment accuracy. Analyst evaluation/judgment may be more relevant to the analysis of assignments than are statistical tests.

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