A Sensitivity Evaluation of the Traffic Assignment Process

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The nature of the input and the nature of the output (computer printout that gives an impression of very precise and accurate traffic volumes for each link) lend a very deterministic appearance to the traffic assignment process. This paper reports an investigation of the sensitivity of the assignment results to the inputs from the preceding modeling phases (1). Additionally, analyses of the assignment results produced by different trip matrices provide a means of evaluating the sensitivity of various commonly used measures of assignment accuracy.

METHOD OF STUDY

A better-worse approach was used in developing data for analyzing the sensitivity of the measures of accuracy of traffic assignment results. Four different trip matrices were used to generate different traffic assignments to one network. The existing network for the Tyler, Texas, Urban Transportation Study was used for test and evaluation.

The better-worse gradient hypothesized that the least desirable assignment (i.e., the worst case) would result from a stochastic trip matrix constrained only to total trips. The fully modeled trip matrix developed in the urban transportation study was used as the standard for comparison in the analyses. The four matrices used in the analyses are defined as follows:

Stochastic matrix 1—a stochastic trip matrix constrained only to the total trips for the urban area,

Stochastic matrix 2—a stochastic trip matrix constrained to the total trips as well as to the desired trip length frequency for the urban area,

Stochastic matrix 3—a stochastic trip matrix constrained to the total trips, the desired trip length frequency, and the desired trip ends at each external station for the urban area, and

Existing trip matrix—the fully modeled trip matrix as developed and used in the urban transportation study.

Analyses

Comparison of the three stochastic matrices with the existing fully modeled matrix indicates that these matrices represent significant differences at both the zonal level (i.e., comparison of zonal trip ends) and at the zonal interchange level (i.e., cell by cell comparison of the trip matrices). An indication of the differences observed at the zonal level is shown below.

Matrix	Range of Trip Ends per Zone	Matrix	Range of Trip Ends per Zone
1	2000 to 3000	3	500 to 14 000
2	500 to 4500	Existing	0 to 15 500

The assignment analyses used a variety of common measures such as vehicle miles of travel (VMT), screenlines, cutlines, and travel routes. They also focused on various statistical measures of link differences (i.e., assigned volume minus counted volume) by counted volume group such as mean differences, standard deviation of the differences, percent standard deviation, RMS error, and percent RMS error.

The results of these analyses indicated that the fully modeled existing trip matrix gave consistently superior assignment results. The most important observations from these analyses, however, were that the assignment results from the stochastic matrices were not nearly as different as had been expected in view of the major differences at the zonal and zonal interchange levels reflected by the matrices.

Comparison of these assignments with those from various urban transportation studies indicated that the results obtained using stochastic matrices 2 and 3 were consistently well within the range of accuracy observed in other studies. Of 10 recent studies in Texas, only 3 had a smaller total percent RMS error than the assignment using stochastic matrix 3. Analysis of the percent RMS error by five volume groups (Figure 1) indicated that the stochastic assignments compare favorably at volumes greater than 4000.

Comparison of assigned to counted volumes for 17 cutlines shows that assignment 1 (i.e., the assignment using stochastic matrix 1) generally resulted in over assignment, but that assignments 2 and 3, as well as the existing trip assignment, tend to be underassigned. As shown below, assignment 3 was consistently better than the other stochastic matrix assignments in the percent of cutlines with assigned volumes within a stated percent difference from the ground counts, but not as good as the existing trip assignment.

Stated Percent Difference From Ground Count	Percent of Cutlines by Assignment 1	2	3	Existing Trip
±10	24	29	35	47
±15	41	41	47	71
±20	47	41	53	76
±25	47	47	71	100
±50	76	94	100	100

These results indicate that, while the fully modeled existing matrix gives the best assignment results, the stochastic matrices with the trip length frequency constraint give reasonable assignment results.

Evaluation

Measures of goodness such as percent RMS error, error range, and standard deviation (type II measures) showed the greatest improvement between assignment 3 and the existing trip assignment. VMT, travel routes, cutlines, and screenline (type I measures) all showed the greatest improvement between assignments 1 and 2. Thus, the type I measures appear to be relatively more sensitive to the trip length frequency than do the type II measures. However, the type II measures are more sensitive to the distribution of zonal trip ends. The sensitivity of the type I and type II measures (shown in italics) to the trip length frequency and the distribution of zonal trip ends appears to relate in the following manner:

Increasing Sensitivity to Trip Length Frequency ↑

VMT
Travel Route
Mean Difference
Cutline
Screenline

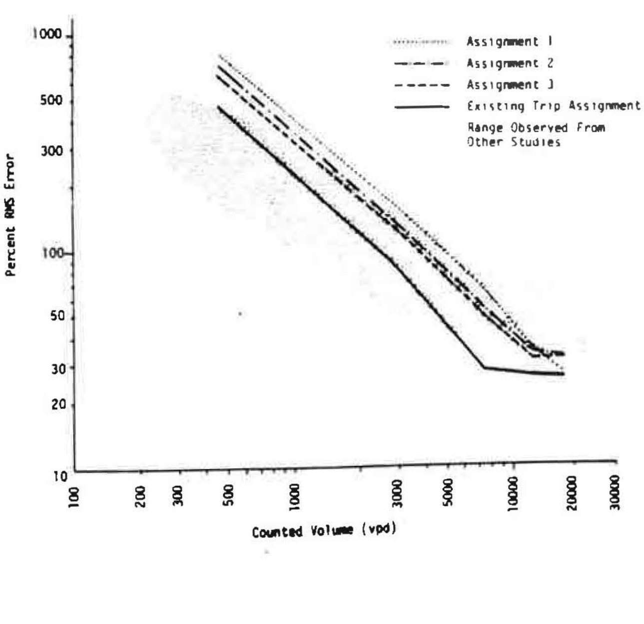
Error Ranges
Percent RMS Error
Standard Deviation

↓ Increasing Sensitivity to the Distribution of Zonal Trip Ends

This suggests that, as the measures are listed from top to bottom, there is a decreasing tendency to mask matrix inaccuracies. As a measure of the accuracy of an assignment, VMT is the least discriminating of the eight measures analyzed, while percent RMS error is the most discriminating. (Standard deviation probably is most sensitive to the distribution of trip ends, but it is difficult to know a reasonable value of standard deviation for any assignment because it is so dependent on network size.)

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

Figure 1. Percent RMS error as a function of counted volume.



Interpretation

As in virtually all urban transportation studies, the Tyler zonal structure tends to reflect the geographical distribution of activities in the urban area. This may be illustrated by subdividing the area into four concentric rings: Ring 1 consists of the CBD; rings 2 and 3 comprise the remainder of the developed urban area; and ring 4 contains those zones in the fringe area. As the intensity of activities within a ring (reflected in the trip ends per square mile) declines, the average number of zones per square mile tends to decline in a similar manner.

The application of the trip length frequency constraint tends to increase the trip ends in rings 1 and 2 (i.e., the CBD and the inner portion of a developed urban area) where the more intense activities are reflected in the average number of zones per square mile. This simply reflects the disproportionate opportunities to travel at the shorter separations (i.e., 1 to 5 min) within rings 1 and 2, which results from the smaller zone sizes in these rings. The zonal structure imposed on the urban area is, therefore, a major determinant of the trip end distribution resulting from the stochastic matrices. For example, if the zonal structure is redefined such that the CBD consists of only two zones, the resulting trip ends will substantially underestimate the desired trip ends within the CBD. In essence, the zone structure provides a crude tool for a distribution of activities in the urban area.

IMPLICATIONS RELATIVE TO ORIGIN-DESTINATION TRIP TABLES

Previous research, based on a 100 percent home interview survey of three selected zones (2), showed that the estimates of zonal trip ends, based on the expansion of home interview data from that zone, are subject to substantial error. For example, the observed expected error ranges at the 95 percent probability level varied from ±32 to ±66 percent, when using a 5 percent sampling rate for a zone containing 424 occupied dwelling units. Other research (3), using the same data base, demonstrated that estimates of interchange volumes from expanded survey data are subject to even greater variance of estimate than the zonal trip ends.

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

In spite of inaccuracies, expanded origin-destination trip tables provide good estimates of total trips and trip length frequency for the urban area, and at least a crude estimate of the geographical distribution trip ends and travel patterns. From the perspective provided by the stochastic matrices, it is not surprising that the expanded origin-destination trip tables generally give reasonable assignment results and that mathematical modeling of urban travel patterns gives even better results.

While the comparisons of trip ends and travel patterns indicate that there are significant differences between assignment 3 and the existing trip matrices, the differences in the assignment results, due to their aggregative nature, are not nearly as significant. This suggests that the assignment results are not overly sensitive to the results of the preceding modeling phases (i.e., the trip generation and trip distribution phases). Therefore, a simplified or short-cut trip generation analysis procedure might be used in conjunction with traditional distribution and assignment models for preliminary system evaluations.

The land use patterns could be described by a map reflecting the desired land use categories. These categories should be kept reasonably simple but have sufficient detail to reasonably describe the urban area being studied. In addition, a number of special land use categories to handle unusual situations may be used. With a description of the land use categories in each zone (i.e., the number of acres or of units of each land use category within a zone), a set of vehicle trip generation rates consistent with the land use categories may be applied to determine the zonal productions and attractions. The resulting geographical distribution of trip ends will be adequate input to the subsequent trip distribution and assignment procedures to yield acceptable assigned volumes for preliminary system evaluation.

CONCLUSIONS

Due to the aggregative nature of the assignment procedure, many of the differences observed at the zonal and zonal interchange levels tend to disappear in the assignment results (1, 4). This implies that much of the precision in the preceding modeling phases (i.e., trip generation and trip distribution phases) can be sacrificed while still producing reasonably accurate assignment results. Therefore, abbreviated or sketch planning techniques should produce assignment results of sufficient accuracy for valid evaluation and comparison of system alternatives.

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