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16. Abstract

The hypothesis to be tested under this study was that improved 24-hour assignment results could be achieved by implementing time-of-day assignment procedures. The objectives of the study were:

1. To quantify the improvements in the 24-hour assignment results which can be obtained from using time-of-day modeling techniques in the development of 24-hour volume estimates.
2. To measure the impact of the time-of-day modeling approach on mobile source emission estimates versus those developed using 24-hour assignment results factored to represent time-of-day volume estimates.

The Houston-Galveston regional travel models and base year data were selected as the data base for this study.

Neither assignment technique emerged as clearly better in replicating the count-based volume estimates. These results suggest that the users could feel equally comfortable in estimating 24-hour volumes for the Houston-Galveston region from either the four time-of-day assignments or the traditional 24-hour assignment. Likewise, neither assignment technique emerged as the better approach for developing emission estimates. There were sufficient differences in the mobile source emission estimates to suggest that the same assignment methodology should be used to compare alternatives to assure that the differences in the emission estimates would be attributable to differences in the alternatives and not to differences in the assignment methodology. Finally, a proposed set of impedance adjustment functions was developed, which is expected to produce better speed results within the assignment process for time-of-day assignments.

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IMPROVING ASSIGNMENT RESULTS FOR AIR QUALITY ANALYSES

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IMPLEMENTATION STATEMENT

This study compared two assignment procedures in terms of their ability to replicate observed 24-hour volumes and their impact on mobile source emission estimates. The basic hypothesis to be tested under this study was that improved 24-hour assignment results can be achieved by implementing time-of-day assignment procedures. Neither assignment technique emerged as clearly better in replicating the count based volume estimates. These results suggest that users could feel equally comfortable in estimating 24-hour volumes for the Houston-Galveston region from either the four time-of-day assignments or the traditional 24-hour assignment. Likewise, neither assignment technique emerged as the better approach for developing emission estimates. Finally, a proposed set of impedance adjustment functions was developed which expected to produce better speed results within the assignment process for time-of-day assignments. The proposed impedance adjustment curves will need further testing before implementation.

This report has not been converted to metric units because it was developed using the Environmental Protection Agency's MOBILE emission factor model. As of the publication of this report, English units are required for MOBILE, and inclusion of metric equivalents could cause some user input error.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation. Additionally, this report is not intended for construction, bidding, or permit purposes. Jimmie D. Benson, P.E. Number 45900, was the Principal Investigator for the project.

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SUMMARY

Emission inventories and conformity analyses are required for the nonattainment areas in Texas. The Houston-Galveston region is the only region in Texas which uses time-of-day assignments for the emission inventories and conformity analyses. In the other nonattainment areas, the mobile source emissions estimates are developed using the traditional 24-hour capacity restraint assignment results. To enhance the quality of the air quality analyses in the other nonattainment areas, it was proposed that an improved method for developing 24-hour capacity restraint assignments (i.e., time-of-day assignments) should be investigated. The hypothesis to be tested under this study was that improved 24-hour assignment results could be achieved by implementing time-of-day assignment procedures. The objectives of the study were:

1. To quantify the improvements in the 24-hour assignment results which can be obtained from using time-of-day modeling techniques in the development of 24-hour volume estimates.
2. To measure the impact of the time-of-day modeling approach on mobile source emissions estimates versus those developed using 24-hour assignment results factored to represent time-of-day volume estimates.

The Houston-Galveston regional travel models and base year data were selected as the data base for this study. This region was selected for the advantages offered by its data base. The study area is a major metropolitan area which experiences significant highway congestion during peak periods. It is one of the nonattainment areas in Texas and the only severe nonattainment area. Further, the base year 24-hour volumes based on traffic counts have been estimated for all links. A set of time-of-day models has already been developed and implemented for the region, which can be utilized for this study.

The first objective of the study was to determine if the Houston-Galveston time-of-day modeling approach provides a better estimate of 24-hour link volumes than the traditional 24-hour assignment models. The time-of-day models were applied to develop separate time-of-day assignments. These time-of-day assignment results were then summed to estimate the 24-hour link volumes and compared to the 24-hour counts. In parallel, a traditional 24-hour assignment was performed, and the results were compared to the 24-hour counts.

Macro-level analysis of the 24-hour assignment results demonstrated that both assignment techniques produced similar results in terms of both VMT and cutlines. When compared to counts, the time-of-day assignment produced only slightly better results than the 24-hour assignment. The micro-level measures indicated that the 24-hour assignment produced somewhat better results relative to the count estimates. Neither assignment technique emerged as clearly better in replicating the count-based volume estimates. These results suggest that the users could feel equally comfortable in estimating 24-hour volumes for the Houston-Galveston region from either the four time-of-day assignments or the traditional 24-hour assignment.

The second objective of the study was to measure the impact of the assignment results from the two assignment techniques on mobile source emissions estimates. The mobile source emissions estimates were developed using the Texas Mobile Source Emissions Software - Version 2. With respect to emission estimates, the study revealed that both assignment techniques produced very similar results. Because the assignment results were close, it was not surprising that the emissions estimates would also be close. Neither assignment technique emerged as the better approach for developing emission estimates. There were sufficient differences in the mobile source emissions estimates to suggest that the same assignment methodology should be used to compare alternatives to assure that the differences in the emission estimates would be attributable to differences in the alternatives and not to differences in the assignment methodology.

TTI also developed a set of proposed impedance adjustment functions which are expected to produce better speed results within the assignment process for time-of-day assignments. These impedance adjustment functions were developed using the detailed speed models developed for the Houston-Galveston region. Since the proposed impedance adjustment functions are substantially simplified versions of the detailed models, they cannot be expected to be as precise or accurate. Nevertheless, they can be expected to produce better speed estimates during the assignment process than the current Texas impedance adjustment function. It is not clear what impact they will have on assignment results. It is recommended that the proposed curve be tested and evaluated in terms of both speed estimates and the assignment results.

I. INTRODUCTION

Emission inventories and conformity analyses are required for the nonattainment areas in Texas. The Houston-Galveston region is the only region in Texas which uses time-of-day assignments for the emission inventories and conformity analyses. In the other nonattainment areas, the mobile source emissions estimates are developed using the traditional 24-hour capacity restraint assignment results. To enhance the quality of the air quality analyses in the other nonattainment areas, it was proposed that an improved method for developing 24-hour capacity restraint assignments (i.e., time-of-day assignments) should be investigated. The hypothesis to be tested under this study was that improved 24-hour assignment results can be achieved by implementing time-of-day assignment procedures.

BACKGROUND

Traditionally the Texas Department of Transportation has relied heavily on the forecast 24-hour highway traffic assignments for a variety of purposes including project ranking and Commission decisions, project development, analysis of highway alternatives, corridor analyses, geometric design, and pavement design. The air quality analyses for emission inventories and conformity analyses are placing increased emphasis on the Department's traffic assignment capabilities. Time-of-day assignments are being employed in the Houston-Galveston region to address the air quality requirements. In the Houston-Galveston region, the vehicle trip tables (by purpose) are factored to represent the various time periods comprising the day. Assignments are performed for each of the time periods and are used to estimate the speeds and emissions for the time period. A simpler approach is employed in the other nonattainment areas in Texas. These areas rely on the more traditional 24-hour assignments as the basic input to their air quality analyses. The 24-hour link volumes are factored to represent the various time periods within the day.

The Houston-Galveston time-of-day modeling techniques were originally implemented to focus on peak-period travel for planning purposes (1). To meet the needs of air quality analyses, these techniques have been extended to represent other time periods comprising the day (2,3,4). While the Houston-Galveston approach would appear to be a more sophisticated approach than the post-assignment factoring procedures used in the other nonattainment areas, it also requires a great deal more modeling effort and is a much more expensive process. With the many pressing deadlines to be met for the air quality analyses, little time has been available to take a critical look at these modeling techniques. This study begins this process.

STUDY APPROACH

The first issue addressed by this study was to determine if the Houston-Galveston time-of-day modeling approach provides a better estimate of 24-hour link volumes than the old, traditional 24-hour models. The hypothesis was that it would seem reasonable to expect that by splitting the 24-hour day into time periods and performing separate assignments representing the morning peak travel, the midday travel, the afternoon peak travel, and the overnight travel (i.e., the late evening and early morning travel) the assignment models would be more sensitive to capacity issues and produce better volume estimates than the traditional approach of assigning a single 24-hour trip table to a 24-hour network using 24-hour capacities. Houston-Galveston base year networks (with 24-hour count data) and trip tables were used to test this hypothesis. The Houston-Galveston time-of-day models were applied to develop separate time-of-day assignments. These time-of-day assignment results were then summed to estimate the 24-hour link volumes. These summed time-of-day assignment results were then compared to the 24-hour counts. In parallel, the traditional 24-hour trip table was assigned to the 24-hour network, and the assigned volumes were compared to the 24-hour counts.

The second set of analyses addressed the effect of the assignment results on the air quality analyses. The analyses used the Houston-Galveston base year assignment results. Mobile source emissions estimates were developed using the time-of-day assignment results (i.e., the approach used to develop the emissions inventory estimates for the Houston-Galveston region).

The other nonattainment areas in Texas (e.g., the Dallas-Fort Worth region, the El Paso region, and the Beaumont-Port Arthur region) use 24-hour assignments in their air quality analyses and perform post-assignment factoring to estimate time-of-day volumes. Since time-of-day assignments were not available for these areas, they were not included in this study. New travel surveys have been completed or are in progress for these regions as well as for the Houston-Galveston region. These surveys will be used to update each region's travel models. The results from this study will be helpful to these areas for guidance in updating their models.

The objectives of this study were:

1. To quantify the improvements in the 24-hour assignment results which can be obtained from using time-of-day modeling techniques in the development of 24-hour volume estimates.
2. To measure the impact of the time-of-day modeling approach on mobile source emissions estimates versus those developed using 24-hour assignment results factored to represent time-of-day volume estimates.

Currently, the time-of-day model results are used only for the emission estimates for air quality analyses in the Houston-Galveston region. The results of these analyses can provide better direction for further development, research, and data collection to support time-of-day modeling. It is also anticipated that the time-of-day model results will prove useful for corridor analyses.

WORK PLAN TASKS

This study utilizes data, networks, and trip tables from the Houston-Galveston region. Since the Houston-Galveston region has already implemented the time-of-day modeling procedures to produce separate assignments by time period, the model applications and analyses will be performed for the Houston-Galveston region. The following outlines the tasks performed in this study.

Task 1: Data Base Acquisition and Preparation

The first task was to obtain copies of the computer data sets that contained the trip tables (by purpose), the base year networks, and other data needed for the application of the travel models and the emission models. TTI has worked closely with the Department and the Houston-Galveston Area Council (H-GAC) in updating their regional models and in developing and implementing their time-of-day models. TTI has immediate access to all data sets needed for the Houston-Galveston applications.

Task 2: Model Applications

The work programmed under this task focused on the application of the travel demand models and the emission models. The following describes the model applications that were performed under this task.

Initially, a traditional 24-hour capacity restraint assignment was performed. The new equilibrium assignment procedure (implemented under Study 1153) was used to perform the assignments for the Houston-Galveston region.

Time-of-day trip tables were developed by factoring the individual trip tables by purpose and converting them from a production-to-attraction orientation to an origin-to-destination orientation. These trip tables were combined and used to perform time-of-day assignments by time period. Again, the new equilibrium procedure was used for these assignments.

Mobile source emissions models were applied using both the 24-hour assignment and the time-of-day assignments. The *Texas Mobile Source Emissions Software* (5) were used to develop the mobile source emissions estimates used in this study. The 24-hour assignment results were factored to represent the various time periods in the day and used to develop a set of emission estimates for the region. The corresponding separate time-of-day assignments were then used to develop a second set of emission estimates for the region. These data were then analyzed to quantify the impact on the emission estimates for the region which resulted from using the two approaches for developing 24-hour assignment volume estimates.

Task 3: Assignment Analyses

The work efforts under this task were directed toward quantifying the improvements in the 24-hour assignment results which were obtained by using time-of-day models to estimate 24-hour volumes (i.e., Objective 1 of this study). Base year assignments were performed so that the 24-hour count data could be used as the objective measure for comparison of assignment results. The traditional 24-hour assignment results were compared to the 24-hour counts. The time-of-day assignments were then summed to produce new 24-hour assignment estimates, and these results were compared to the same count data. Various macro-measures and micro-measures were employed in the comparisons. The macro-measure comparisons included counted versus assigned vehicle miles of travel stratified by facility type and counted versus assigned volumes for selected cutlines. For the micro-measure comparisons, the links with count data were grouped by facility type and the following comparisons performed: average counted volume, average assigned volume, average difference, root-mean-square error (RMSE); and the percent root-mean-square error (% RMSE). The links were also grouped by volume groups and the micro-measures computed and compared. Finally the analyses focused on the subset of links with high counted volume-to-capacity (v/c) ratios to determine which assignment technique best replicates these conditions. These analyses were performed using the base year Houston-Galveston regional assignment results.

Task 4: Emissions Analyses

The work efforts under this task were directed toward quantifying the impact on the emission estimates for each region which resulted from using the two approaches for developing 24-hour assignments volume estimates (i.e., Objective 2 for this study). The emission estimates were developed for three types of emissions (i.e., VOC, CO and NOx) using the IMPSUM program. The results for each emission type were stratified by county and roadway type. The differences in the emission estimates using the two types of assignment results were computed and compared for each region. The subsequent analyses identified the differences in the assignment results which contributed to these the differences in the emission estimates.

Task 5: Investigation of Alternative Impedance Adjustment Function to Improve Speed Estimates in Assignments

The speed estimates currently used in the capacity restraint assignments are not reflective of operational speeds. Post-assignment speed models have been used in nonattainment areas to estimate speeds for the emission analyses. The impedance adjustment function (sometimes referred to as a volume delay function) which is used in most Texas urban areas was implemented in the Texas Package in 1979. It is a variation of the classic BPR impedance adjustment function. The impedance adjustment produces the adjusted speed based on the link's weighted average v/c ratio.

With the implementation of the equilibrium assignment procedures, the Texas Package software was modified to accept different impedance adjustment functions by functional class. The work performed under this task represents the first effort to investigate alternative impedance adjustment functions for use in the Texas Package. Under this task, TTI developed a proposed set of impedance adjustment curves which was expected to produce more realistic speed results within the assignment process for time-of-day assignments than the Texas impedance adjustment function.

II. DATA BASE AND MODELS

The Houston-Galveston regional travel models and base year data were selected as the data base for this study. Some of the salient advantages offered by this data base are:

- The study area is a major metropolitan area which experiences very significant highway congestion during peak periods;
- The study area is one of the nonattainment areas in Texas and the only severe non-attainment area;
- The base year 24-hour volumes based on traffic counts have been estimated for all links except centroid connectors;
- Two types of time-of-day models (i.e., a trip table factoring method and a post-assignment factoring method) have been implemented and used in air quality analyses for the region;
- Substantial morning and afternoon peak-period speed data are available for the network.

The travel models for the region were developed and implemented in a cooperative effort between the Houston-Galveston Area Council (i.e., the MPO for the region), the Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority of Harris County (METRO). TTI assisted the region in the travel model development and validation. The purpose of this chapter is to provide a brief overview of the data base and models used in this study.

NETWORK, ZONES, AND DEMOGRAPHICS

The study area is an eight county region consisting of Harris County and the surrounding seven counties (Brazoria County, Fort Bend County, Waller County, Montgomery County, Liberty County, Chambers County, and Galveston County). The eight-county area encompasses roughly 8,000 square miles. The 1985 base year population, households, and employment by county for the region are summarized in Table II-1. Harris County represents over 75 percent of the region's population and over 85 percent of the region's employment.

Table II-1
Base Year Demographics

County	Population	% of Region	Households	% of Region	Employment	% of Region
Harris	2,723,888	76.1%	981,444	77.8%	1,495,577	86.1%
Brazoria	188,953	5.3%	60,192	4.8%	63,229	3.6%
Chambers	19,003	.5%	6,406	.5%	7,134	.4%
Fort Bend	187,855	5.2%	57,704	4.6%	40,586	2.3%
Galveston	215,386	6.0%	75,669	6.0%	74,033	4.3%
Liberty	56,014	1.6%	19,289	1.5%	12,773	.7%
Montgomery	164,941	4.6%	53,299	4.2%	37,972	2.2%
Waller	23,757	.7%	7,068	.6%	6,469	.4%
8-County Totals	3,579,797	100.0%	1,261,071	100.0%	1,737,773	100.0%

The model chain makes use of a nested system of analysis zones which at its most detailed level consists of 2,598 internal zones and 45 external stations. The number of zones used to represent each county is summarized in Table II-2. Trip generation, trip distribution, and highway assignment are performed at the detailed analysis zone (2,643) level. The 2,643 zones are collapsed to roughly 800 zones for transit mode choice analysis. The lesser detail is primarily a function of (1) the geographic size of the area served by transit and (2) restrictions in the mode choice software.

Table II-2
Zones and Network

County	Approx. Area (sq. mi.)	Highway Zones	Highway Links[1]	Highway Centerline Miles[1]	Highway Lane Miles[1]
Harris	1,723	1,539	5,880	2,499.5	8,461.2
Brazoria	1,423	279	749	607.3	1,433.9
Chambers	616	42	149	244.2	572.3
Fort Bend	869	179	555	468.8	1,146.2
Galveston	399	225	710	390.9	1,099.1
Liberty	1,180	79	271	374.4	810.7
Montgomery	1,090	197	526	540.0	1,227.6
Waller	509	58	185	253.0	569.4
8-County Totals	7,809	2,598	9,025	5,378.1	15,320.4

[1] Excludes zonal centroid connectors

The highway networks used in the analysis of highway travel in the region are also detailed in nature. The base year network contains 5,101 centroid connectors (i.e., 10,202 one-way centroid connectors) and 9,025 links (i.e., 17,870 one-way links). The 9,025 links represent 393 centerline miles of freeway and 4,982 centerline miles of arterials and collectors. The number of links by county is summarized in Table II-2. Also summarized in Table II-2 are the network centerline miles and lane miles by county.

REGIONAL TRAVEL MODELS

The travel demand in the Houston area is analyzed using the traditional four-step process. H-GAC maintains its own trip generation software while utilizing TxDOT's Texas Trip Distribution Model and Texas Large Network Assignment Package for the distribution and assignment phases of the process. Transit mode choice analysis is performed by METRO using a multi-nominal logit model.

The primary components of the travel model chain currently in use were developed and/or calibrated for the 1985 base year. The principal data base used for the development and calibration of the travel demand model chain was developed from both a fall 1984 household travel survey and a spring 1985 transit survey. The models were recently revalidated to the year 1990. The 1990 validation efforts paralleled this study and were not available for use in this study.

Trip Purposes and Trip Generation

The trip generation and trip distribution for the Houston-Galveston region is performed using eight trip purposes:

- Homebased work person trips
- Homebased school person trips
- Homebased shop person trips
- Homebased other person trips
- Non-homebased person trips
- Truck-taxi vehicle trips
- External-local vehicle trips
- External-thru vehicle trips

The person trip generation models were developed using the 1984 household travel survey data. The person trip production rates per household are stratified by five household income groups and five household size groups. The person trip attraction models were also developed using the 1984 household travel survey data. The truck-taxi and external vehicle models were based on earlier models developed for the region.

Trip Distribution

The trip distributions for the six internal trip purposes and the external local trip purpose were performed using the ATOM2 model of the Texas Trip Distribution Package. The ATOM2 model differs from the traditional gravity model in its consideration of zone size in the trip distribution process. The gravity model F-factors and bias factors (sometimes refered to as K-factors) were calibrated for the 1985 base year using the ATOM2 model. The external-thru trip tables for the region were developed using a FRATAR model (6, 7).

Conversion of Person Trips to Vehicle Trips

In the Houston-Galveston region, the highway and transit analyses are performed using two different levels of zonal detail. The mode choice estimates are prepared at an 800-zone level for the transit analysis zones, while the trip distributions and highway assignments are performed at a 2,600-zone level. The highway analysis zones are nested in the transit analysis zones. The person trip distributions are performed at the 2,600-zone level and aggregated to the 800-zone level for use in the transit analyses. Following the transit analyses, the transit mode shares by trip purpose are computed at the sector interchange level. The mode shares are applied to the 2,600- zone person trip tables to estimate the highway person trips. The estimated auto occupancies (by trip purpose) are applied to the highway person trips to develop the vehicle trip estimates. The conversion of the 2,600-zone 24-hour person trip tables to 2,600-zone 24-hour vehicle trip tables is accomplished using software implemented in the Texas Trip Distribution package for HOV modeling. Table II-3 summarizes the conversion from person to vehicle trips.

Table II-3
Summary of Base Year Conversion
From Person Vehicle Trips
(8-County Region)

Trip Purpose	Total Person Trips	Percent Using Transit	Average Auto Occupancy	Total Vehicle Trips
Homebased Work	2,163,383	5.56	1.14	1,794,357
Homebased Shop	1,330,101	26.13*	2.33	422,150
Homebased School	1,438,343	0.45	1.34	1,065,447
Homebased Other	4,754,078	0.55	1.29	3,672,709
Non-Homebased	3,731,389	0.99	1.24	2,975,035
Weighted Average	13,417,294	4.01	1.30	9,929,698

* Includes both public transit and school bus trips

24-Hour Highway Assignment

The 24-hour vehicle trip tables (at the 2,600-zone level) are summed and converted from production-to-attraction format to origin-to-destination format. The 24-hour assignment was performed using the equilibrium assignment option in the ASSIGN SELF-BALANCING routine of the Texas Largenet Assignment Package. The 24-hour assignment is performed using nondirectional speeds and nondirectional 24-hour capacities. Tables II-4 through II-7 show the 24-hour capacities for freeways, tollways, arterials, and collectors. They are stratified by functional class and area type.

Table II-4
24-Hour Capacities - Freeways

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Radial Freeways Without Frontage Roads	4	89,500	100,500	90,500	76,000	57,500
Radial Freeways Without Frontage Roads	6	134,500	151,000	135,500	114,000	86,500
Radial Freeways Without Frontage Roads	8	179,500	201,500	180,500	152,000	115,000
Radial Freeways Without Frontage Roads	10	224,500	252,000	226,000	190,000	144,000
Radial Freeways Without Frontage Roads	12	269,000	302,000	271,000	-	-
Radial Freeways Without Frontage Roads	14	314,000	352,500	316,000	-	-
Radial Freeways Without Frontage Roads	16	359,000	403,000	361,500	-	-
Radial Freeways With Frontage Roads	4	105,500	116,500	106,500	92,000	73,500
Radial Freeways With Frontage Roads	6	150,500	167,000	151,500	130,000	102,500
Radial Freeways With Frontage Roads	8	195,500	217,500	196,500	168,000	131,000
Radial Freeways With Frontage Roads	10	240,500	268,000	242,000	206,000	160,000
Radial Freeways With Frontage Roads	12	285,000	318,000	287,000	-	-
Radial Freeways With Frontage Roads	14	330,000	368,500	332,000	-	-
Radial Freeways With Frontage Roads	16	375,000	419,000	377,500	-	-
Circumferential Freeways Without Frontage Roads	4	85,000	100,500	94,500	83,000	68,000
Circumferential Freeways Without Frontage Roads	6	120,500	151,000	141,500	124,000	102,000
Circumferential Freeways Without Frontage Roads	8	160,500	201,500	189,000	165,500	136,000
Circumferential Freeways Without Frontage Roads	10	200,500	252,000	236,000	207,000	170,000
Circumferential Freeways Without Frontage Roads	12	241,000	302,000	283,500	-	-
Circumferential Freeways Without Frontage Roads	14	281,000	352,500	330,500	-	-
Circumferential Freeways Without Frontage Roads	16	321,000	403,000	377,500	-	-
Circumferential Freeways With Frontage Roads	4	101,000	116,500	110,500	99,000	84,000
Circumferential Freeways With Frontage Roads	6	136,500	167,000	157,500	140,000	118,000
Circumferential Freeways With Frontage Roads	8	176,500	217,500	205,000	181,500	152,000
Circumferential Freeways With Frontage Roads	10	216,500	268,000	252,000	223,000	186,000
Circumferential Freeways With Frontage Roads	12	257,000	318,000	299,500	-	-
Circumferential Freeways With Frontage Roads	14	297,000	368,500	346,500	-	-
Circumferential Freeways With Frontage Roads	16	337,000	419,000	393,500	-	-

Table II-5
24-Hour Capacities - Tollways

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Radial Tollways Without Frontage Roads	4	57,000	52,000	48,000	41,000	34,000
Radial Tollways Without Frontage Roads	6	85,000	78,000	72,000	62,000	51,000
Radial Tollways Without Frontage Roads	8	114,000	104,000	95,000	82,000	68,000
Radial Tollways Without Frontage Roads	10	142,000	130,000	119,000	103,000	85,000
Radial Tollways Without Frontage Roads	12	171,000	156,000	143,000	-	-
Radial Tollways Without Frontage Roads	14	199,000	182,000	167,000	-	-
Radial Tollways Without Frontage Roads	16	228,000	208,000	191,000	-	-
Radial Tollways With Frontage Roads	4	71,500	69,000	64,000	56,000	45,000
Radial Tollways With Frontage Roads	6	99,500	95,000	88,000	77,000	62,000
Radial Tollways With Frontage Roads	8	128,500	121,000	111,000	97,000	79,000
Radial Tollways With Frontage Roads	10	156,500	147,000	135,000	118,000	96,000
Radial Tollways With Frontage Roads	12	185,500	173,000	159,000	-	-
Radial Tollways With Frontage Roads	14	213,500	199,000	183,000	-	-
Radial Tollways With Frontage Roads	16	242,500	225,000	207,000	-	-
Circumferential Tollways Without Frontage Roads	4	60,000	57,000	54,000	49,000	43,000
Circumferential Tollways Without Frontage Roads	6	89,000	85,000	81,000	73,000	65,000
Circumferential Tollways Without Frontage Roads	8	119,000	113,000	108,000	97,000	87,000
Circumferential Tollways Without Frontage Roads	10	149,000	142,000	136,000	122,000	108,000
Circumferential Tollways Without Frontage Roads	12	179,000	170,000	163,000	-	-
Circumferential Tollways Without Frontage Roads	14	208,000	199,000	190,000	-	-
Circumferential Tollways Without Frontage Roads	16	238,000	227,000	217,000	-	-
Circumferential Tollways With Frontage Roads	4	74,500	74,000	70,000	64,000	54,000
Circumferential Tollways With Frontage Roads	6	103,500	102,000	97,000	88,000	76,000
Circumferential Tollways With Frontage Roads	8	133,500	130,000	124,000	112,000	98,000
Circumferential Tollways With Frontage Roads	10	163,500	159,000	152,000	137,000	119,000
Circumferential Tollways With Frontage Roads	12	193,500	187,000	179,000	-	-
Circumferential Tollways With Frontage Roads	14	222,500	216,000	206,000	-	-
Circumferential Tollways With Frontage Roads	16	252,500	234,400	233,000	-	-

Table II-6
24-Hour Capacities - Arterials

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Principal Arterials - With Some Grade Separation	2	19,600	23,000	22,400	20,800	17,400
Principal Arterials - With Some Grade Separation	4	38,000	44,800	43,600	40,500	33,900
Principal Arterials - With Some Grade Separation	6	55,500	65,400	63,600	59,100	49,500
Principal Arterials - With Some Grade Separation	8	74,000	87,300	84,800	78,800	66,000
Principal Arterials - Divided	2	15,000	16,700	16,200	14,400	11,700
Principal Arterials - Divided	4	29,300	32,400	31,500	28,000	22,800
Principal Arterials - Divided	6	42,700	47,300	46,000	40,800	33,200
Principal Arterials - Divided	8	56,900	63,100	61,300	54,400	44,300
Principal Arterials - Undivided	2	13,200	15,400	14,900	13,300	10,800
Principal Arterials - Undivided	4	25,300	29,600	28,700	25,500	20,800
Principal Arterials - Undivided	6	36,600	42,700	41,500	36,900	30,000
Principal Arterials - Undivided	8	48,200	56,300	54,700	48,600	39,600
Other Arterials - Divided	2	13,500	16,200	14,600	12,500	10,500
Other Arterials - Divided	4	26,300	31,500	28,400	24,400	20,500
Other Arterials - Divided	6	38,400	45,900	41,500	35,600	29,900
Other Arterials - Divided	8	51,200	61,300	55,300	47,400	39,900
Other Arterials - Undivided	2	12,500	15,100	13,600	11,700	10,200
Other Arterials - Undivided	4	24,100	29,000	26,200	22,500	19,500
Other Arterials - Undivided	6	34,700	41,900	37,900	32,500	28,200
Other Arterials - Undivided	8	45,800	55,200	49,900	42,800	37,200
Saturated Arterials	2	19,000	21,600	21,200	20,800	15,300
Saturated Arterials	4	37,800	43,000	42,200	41,400	30,600
Saturated Arterials	6	56,400	64,200	63,000	61,800	45,600
Saturated Arterials	8	74,800	85,100	83,500	81,900	60,500

Table II-7
24-Hour Capacities - Collectors

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Major Collectors	2	12,500	14,600	13,200	11,400	8,800
Major Collectors	4	24,100	28,200	25,500	21,800	16,900
Major Collectors	6	34,700	40,600	36,800	31,600	24,400
Major Collectors	8	45,800	53,600	48,400	41,600	32,100
Collectors	2	8,700	10,400	10,200	6,600	3,600
Collectors	4	16,200	19,300	18,900	12,300	6,700
Collectors	6	24,100	28,300	27,800	17,600	9,800
Collectors	8	33,900	39,800	39,100	24,300	13,200

Time-of-Day Highway Assignments

There are, of course, a variety of techniques for estimating peak-period highway volumes. These techniques vary widely in terms of their level of sophistication and in the level of effort required for model development and application. The approaches used for developing peak travel demand estimates can generally be grouped into four categories: Factoring 24-hour assignment volumes, trip table factoring, trip end factoring, and direct generation (8). A vehicle trip table factoring approach is used in the Houston-Galveston region (1, 2, 3, 4). Tables II-8 through II-11 show the peak-hour directional capacities for freeways, tollways, arterials, and collectors. They are stratified by functional class and area type.

Table II-8
Peak-Hour Directional Capacities - Freeways

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Radial Freeways Without Frontage Roads	2	3,947	4,155	4,155	4,099	4,019
Radial Freeways Without Frontage Roads	3	5,920	6,232	6,232	6,149	6,028
Radial Freeways Without Frontage Roads	4	7,894	8,309	8,309	8,198	8,037
Radial Freeways Without Frontage Roads	5	9,867	10,386	10,386	10,248	10,047
Radial Freeways Without Frontage Roads	6	11,841	12,464	12,464	-	-
Radial Freeways Without Frontage Roads	7	13,814	14,541	14,541	-	-
Radial Freeways Without Frontage Roads	8	15,787	16,618	16,618	-	-
Radial Freeways With Frontage Roads	2	4,747	4,955	4,955	4,899	4,819
Radial Freeways With Frontage Roads	3	6,720	7,032	7,032	6,949	6,828
Radial Freeways With Frontage Roads	4	8,694	9,109	9,109	8,998	8,837
Radial Freeways With Frontage Roads	5	10,667	11,186	11,186	11,048	10,847
Radial Freeways With Frontage Roads	6	12,641	13,264	13,264	-	-
Radial Freeways With Frontage Roads	7	14,614	15,341	15,341	-	-
Radial Freeways With Frontage Roads	8	16,587	17,418	17,418	-	-
Circumferential Freeways Without Frontage Roads	2	3,739	4,155	4,155	4,099	4,019
Circumferential Freeways Without Frontage Roads	3	5,297	6,232	6,232	6,149	6,028
Circumferential Freeways Without Frontage Roads	4	7,063	8,309	8,309	8,198	8,037
Circumferential Freeways Without Frontage Roads	5	8,829	10,386	10,386	10,248	10,047
Circumferential Freeways Without Frontage Roads	6	10,594	12,464	12,464	-	-
Circumferential Freeways Without Frontage Roads	7	12,360	14,541	14,541	-	-
Circumferential Freeways Without Frontage Roads	8	14,126	16,618	16,618	-	-
Circumferential Freeways With Frontage Roads	2	4,539	4,955	4,955	4,899	4,819
Circumferential Freeways With Frontage Roads	3	6,097	7,032	7,032	6,949	6,828
Circumferential Freeways With Frontage Roads	4	7,863	9,109	9,109	8,998	8,837
Circumferential Freeways With Frontage Roads	5	9,629	11,186	11,186	11,048	10,847
Circumferential Freeways With Frontage Roads	6	11,394	13,264	13,264	-	-
Circumferential Freeways With Frontage Roads	7	13,160	15,341	15,341	-	-
Circumferential Freeways With Frontage Roads	8	14,926	17,418	17,418	-	-

Table II-9
Peak-Hour Directional Capacities - Tollways

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Radial Tollways Without Frontage Roads	2	3,355	3,355	3,355	3,145	2,921
Radial Tollways Without Frontage Roads	3	5,032	5,032	5,032	4,717	4,381
Radial Tollways Without Frontage Roads	4	6,710	6,710	6,710	6,289	5,841
Radial Tollways Without Frontage Roads	5	8,387	8,387	8,387	7,861	7,301
Radial Tollways Without Frontage Roads	6	10,064	10,064	10,064	-	-
Radial Tollways Without Frontage Roads	7	11,742	11,742	11,742	-	-
Radial Tollways Without Frontage Roads	8	13,419	13,419	13,419	-	-
Radial Tollways With Frontage Roads	2	4,080	4,205	4,155	3,895	3,471
Radial Tollways With Frontage Roads	3	5,757	5,882	5,832	5,467	4,931
Radial Tollways With Frontage Roads	4	7,435	7,560	7,510	7,039	6,391
Radial Tollways With Frontage Roads	5	9,112	9,237	9,187	8,611	7,851
Radial Tollways With Frontage Roads	6	10,789	10,914	10,864	-	-
Radial Tollways With Frontage Roads	7	12,467	12,592	12,542	-	-
Radial Tollways With Frontage Roads	8	14,144	14,269	14,219	-	-
Circumferential Tollways Without Frontage Roads	2	3,355	3,355	3,355	3,145	2,921
Circumferential Tollways Without Frontage Roads	3	5,032	5,032	5,032	4,717	4,381
Circumferential Tollways Without Frontage Roads	4	6,710	6,710	6,710	6,289	5,841
Circumferential Tollways Without Frontage Roads	5	8,387	8,387	8,387	7,861	7,301
Circumferential Tollways Without Frontage Roads	6	10,064	10,064	10,064	-	-
Circumferential Tollways Without Frontage Roads	7	11,742	11,742	11,742	-	-
Circumferential Tollways Without Frontage Roads	8	13,419	13,419	13,419	-	-
Circumferential Tollways With Frontage Roads	2	4,080	4,205	4,155	3,895	3,471
Circumferential Tollways With Frontage Roads	3	5,757	5,882	5,832	5,467	4,931
Circumferential Tollways With Frontage Roads	4	7,435	7,560	7,510	7,039	6,391
Circumferential Tollways With Frontage Roads	5	9,112	9,237	9,187	8,611	7,851
Circumferential Tollways With Frontage Roads	6	10,789	10,914	10,864	-	-
Circumferential Tollways With Frontage Roads	7	12,467	12,592	12,542	-	-
Circumferential Tollways With Frontage Roads	8	14,144	14,269	14,219	-	-

Table II-10
Peak-Hour Directional Capacities - Arterials

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Principal Arterials - With Some Grade Separation	1	1,082	1,160	1,148	1,136	1,110
Principal Arterials - With Some Grade Separation	2	2,106	2,258	2,235	2,212	2,163
Principal Arterials - With Some Grade Separation	3	3,074	3,295	3,262	3,228	3,156
Principal Arterials - With Some Grade Separation	4	4,098	4,395	4,349	4,304	4,209
Principal Arterials - Divided	1	892	883	873	864	814
Principal Arterials - Divided	2	1,738	1,719	1,701	1,684	1,585
Principal Arterials - Divided	3	2,536	2,509	2,483	2,456	2,313
Principal Arterials - Divided	4	3,380	3,346	3,311	3,276	3,084
Principal Arterials - Undivided	1	783	815	807	800	752
Principal Arterials - Undivided	2	1,505	1,566	1,551	1,537	1,447
Principal Arterials - Undivided	3	2,174	2,262	2,242	2,221	2,091
Principal Arterials - Undivided	4	2,865	2,982	2,955	2,925	2,758
Other Arterials - Divided	1	803	857	848	839	789
Other Arterials - Divided	2	1,563	1,668	1,650	1,633	1,538
Other Arterials - Divided	3	2,282	2,434	2,409	2,384	2,244
Other Arterials - Divided	4	3,043	3,246	3,212	3,177	2,991
Other Arterials - Undivided	1	744	799	791	784	762
Other Arterials - Undivided	2	1,430	1,536	1,523	1,507	1,465
Other Arterials - Undivided	3	2,064	2,219	2,199	2,178	2,117
Other Arterials - Undivided	4	2,722	2,925	2,896	2,870	2,790
Saturated Arterials	1	992	992	992	992	954
Saturated Arterials	2	1,975	1,975	1,975	1,975	1,899
Saturated Arterials	3	2,947	2,947	2,947	2,947	2,834
Saturated Arterials	4	3,908	3,908	3,908	3,908	3,759

Table II-11
Peak-Hour Directional Capacities - Collectors

FACILITY TYPE	Number of Lanes	AREA TYPE				
		CBD	Urban	Inner Suburban	Fringe Suburban	Rural
Major Collectors	1	744	776	768	761	740
Major Collectors	2	1,430	1,492	1,479	1,463	1,422
Major Collectors	3	2,064	2,154	2,134	2,115	2,055
Major Collectors	4	2,722	2,839	2,812	2,786	2,708
Collectors	1	563	590	589	488	404
Collectors	2	1,046	1,097	1,094	912	757
Collectors	3	1,551	1,612	1,612	1,304	1,101
Collectors	4	2,181	2,268	2,268	1,801	1,483

In the Houston-Galveston time-of-day models, the trip table factoring is performed on the 24-hour production-to-attraction vehicle trip tables by trip purpose. The 1984 household travel survey data were used develop the time-of-day factors for most of the trip purposes. The truck-taxi and external time-of-day factors were develop using travel survey data from other urban areas. The trip table factoring program basically performs two functions: (1) It factors the 24-hour trips to represent the desired time period, and (2) It converts the travel from production-to-attraction orientation to an origin-to-destination orientation. Two different factors, therefore, are needed for each trip purpose: One factor estimates the percentage of 24-hour travel expected to occur in the subject time period, and the other estimates the portion of that travel expected to occur in the production-to-attraction direction. Table II-12 presents an example of the time-of-day trip table factors by trip purpose for four time periods(2).

Table II-12
Houston-Galveston Time-of-Day Factors (9)

Trip Purpose	Vehicle Trip Table Factoring Information by Time Period							
	6:30 a.m. to 8:30 a.m.		8:30 a.m. to 3:30 p.m.		3:30 p.m. to 6:30 p.m.		6:30 p.m. to 6:30 a.m.	
	Percent VMT[a]	Portion P-to-A[b]	Percent VMT[a]	Portion P-to-A[b]	Percent VMT[a]	Portion P-to-A[b]	Percent VMT[a]	Portion P-to-A[b]
Homebased Work[c]	34.78	0.980	15.26	0.666	29.47	0.022	20.49	0.583
Homebased School[c]	45.20	0.993	30.32	0.209	18.56	0.078	5.92	0.264
Homebased Shop[c]	3.96	0.877	37.51	0.494	29.91	0.275	28.63	0.312
Homebased Other[c]	11.99	0.893	31.53	0.583	26.03	0.304	30.45	0.341
Non-homebased[c]	6.95	0.500	60.58	0.500	22.75	0.500	9.71	0.500
Truck-Taxi[d]	13.04	0.500	57.68	0.500	20.19	0.500	9.10	0.500
External[d]	9.61	0.550	41.80	0.500	22.92	0.450	25.66	0.500

[a]Percentage of the daily vehicle miles of travel for the subject trip purpose which occurs in the subject time period.
[b]Portion of the travel during this time period which occurs in the production-to-attraction direction.
[c]Estimates developed using the 1984 Houston-Galveston Household Travel Survey Data.
[d]Estimates developed for Houston using data from other urban areas.

To improve the directionality of time-of-day non-homebased (NHB) travel estimates for major activity centers (e.g., the Houston CBD), a hybrid trip end and trip table factoring technique was subsequently implemented. In major activity centers such as the CBD, it was noted that the number of NHB trip destinations substantially exceeded the number of NHB trip origins in the morning peak period and vice-versa in the afternoon peak period. Trip-end factors were developed to estimate the number of NHB origins and NHB destinations by time period for the five major activity centers that have been identified in the Houston region. These five major activity centers are: the Houston Central Business District, the Galleria/Post Oak Area, the Greenway Plaza Area, the Texas Medical Center Area, and the Ship Channel Area.

Similar factors were developed for the balance of the region stratified by area type. Table II-13 summarizes the NHB factors used by major activity center. Table II-14 summarizes the NHB factors by area type. By applying these factors to the 24-hour NHB zonal productions and attractions, the desired NHB origins and NHB destinations for a subject time period are computed for each zone. The desired time-of-day NHB origins and destinations by zone and the 24-hour NHB trip table are input to a FRATAR model to factor the trip table.

Along with the creation of time-of-day trip tables, time-of-day travel networks which reflect the time period of interest (in terms of capacities) are also developed. Once the time-of-day networks and trip tables are created, the trip tables are assigned to the network using the equilibrium assignment option in the PEAK PERIOD CAPACITY RESTRAINT routine in the Texas Largenet

Package (9). Separate assignments were run for each of the four time periods. The results were subsequently combined for analysis and comparison to the traditional 24-hour assignment.

Table II-13
Estimated NHB Time-of-Day Origin and Destination Factors for Major Activity Centers from Houston Travel Survey (8)

TIME PERIOD		MAJOR ACTIVITY CENTERS										BALANCE OF REGION	
		CENTRAL BUSINESS DISTRICT		GALLERIA/ POST OAK		GREENWAY PLAZA		TEXAS MEDICAL CENTER		SHIP CHANNEL AREA			
FROM	TO	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP
6:30am -	8:30am	6.9623	7.8994	5.3160	7.7507	1.1482	5.6086	10.3756	23.5755	13.3179	14.1577	6.4937	5.9800
8:30am -	3:30pm	62.0868	69.5348	64.1197	59.0450	80.9527	61.9605	56.6811	51.2441	58.3855	59.0140	63.6947	64.1009
3:30pm -	6:30pm	27.8128	11.2520	29.5417	17.4733	19.5829	12.2010	33.3718	16.8384	25.7628	15.2937	20.9497	22.8823
6:30pm -	6:30am	9.8040	4.6480	7.1822	9.5713	8.4328	10.1133	3.2035	4.7100	7.0541	7.0142	7.9054	7.9932
12:00am -	12:00pm	106.6659	93.3341	106.1596	93.8404	110.1166	89.8834	103.6321	96.3679	104.5204	95.4796	99.0436	100.9564

Table II-14
Estimated NHB Time-of-Day Origin and Destination Factors by Area Type from Houston Travel Survey (8)

TIME PERIOD		CENTRAL BUSINESS DISTRICT		OTHER FOUR MAJOR ACTIVITY CENTERS		BALANCE OF URBAN		BALANCE OF INNER SUBURBAN		BALANCE OF SUBURBAN & RURAL		TOTAL REGION	
FROM	TO	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP	PERCENT O-TRP	PERCENT D-TRP
6:30am -	8:30am	6.9623	7.8994	7.3893	11.8796	5.6661	6.9683	7.1819	5.8277	6.1170	5.5842	6.5939	6.5939
8:30am -	3:30pm	62.0868	69.5348	65.4096	58.3319	67.3442	65.3660	61.7625	63.3939	63.9634	64.2411	63.7880	63.7880
3:30pm -	6:30pm	27.8128	11.2520	26.7125	15.4360	20.0150	21.5572	21.9794	23.6664	20.2054	22.6805	21.7455	21.7455
6:30pm -	6:30am	9.8040	4.6480	6.7284	8.1128	6.6441	6.4391	7.9697	8.2186	8.5749	8.6336	7.8726	7.8726
12:00am -	12:00pm	106.6659	93.3341	106.2397	93.7603	99.6694	100.3306	98.8935	101.1065	98.8607	101.1393	100.0000	100.0000

III. COMPARISON OF ASSIGNMENT RESULTS USING MACRO-LEVEL MEASURES

The evaluation of the traffic assignment models focuses on their ability to reflect reality (i.e., counted volumes). Measures of how well an assignment reproduces traffic counts can be divided into two groups, macro-level measures and micro-level measures. This chapter presents the comparison of the results using the different models and network parameters using macro-level measures. The comparisons using micro-level measures are presented in Chapter IV.

MACRO-LEVEL MEASURES

The macro-level measures compare aggregate measures of assigned versus counted volumes while the micro-level measures focus on link-by-link differences. Two macro-level measures were used to compare the various assignment results with the counted volumes: Vehicle miles of travel (VMT) and traffic across cutlines (i.e., corridor intercepts or screenlines). A final macro-level measure used to review the assignment results was the iteration weights.

VMT RESULTS

The VMT on a link is computed by multiplying the link's volume by the link's distance in miles. Both the assigned VMT and the counted VMT can be computed and accumulated for comparison.

For the VMT comparisons in this study, the VMT results were cross-classified by functional class and area type. Table III-1 summarizes the counted VMT and the assigned VMT for both the 24-hour assignment and the time-of-day assignment. Table III-2 is similar to Table III-1, except the assigned VMT is summarized as a percentage of the counted VMT. These data provide an indication of some general differences between the results using the different models. Some of the more interesting observations are:

- The total counted VMT for all 9,025 links was 73,102,424. Both assignments produced VMT estimates which were very close to the counted VMT (i.e., within one percent of the counted VMT). The time-of-day assignments produced a total VMT estimate which was only slightly better than the 24-hour assignment.

- The total counted VMT for the 553 freeway links representing the 393 miles of freeway system was 31,979,798 (i.e., nearly 44 percent of the total counted VMT on all 9,025 links). While both assignment techniques produced acceptable results, the time-of-day assignments produced slightly better results than the 24-hour assignment for each of the five area types.
- The total counted VMT for the 1,412 principal arterial links representing 692 miles of principal arterial system was 13,895,757 (i.e., approximately 19 percent of the total counted VMT on all 9,025 links). While both assignment techniques produced generally acceptable results, the 24-hour assignments produced somewhat better results than the time-of-day for four of the five area types. Both assignments were high on the 1.89 miles of principal arterials in the CBD. It should be noted that much of the CBD street system is coded as one-way pairs of arterials and is not designated as either principal or minor arterials. These one-way pair links are included in the "other arterial" category in these tables.
- The total counted VMT for the 5,725 other arterial links representing 3,165 miles of the other arterial system was 25,647,160 (i.e., approximately 35 percent of the total counted VMT on all 9,025 links). Both assignment techniques produced similar results. Neither assignment technique was judged to be better than the other.
- The total counted VMT for the 1,335 collector links representing 1,126 miles of collector streets was 1,579,709 (i.e., approximately 2 percent of the total counted VMT on all 9,025 links). Except in rural areas, the 24-hour assignment generally estimates VMT closer to counted than the time-of-day assignments.
- Both assignments produced similar total VMT by area types. This is not surprising since they were both developed from the same trip tables. The differences in the assignments by area type will primarily be in terms of the path selection and will be reflected in the distribution of VMT by facility type within an area type.
- In four of the five area types (i.e., except for the CBD), the time-of-day assignments produced total VMT estimates closer to the counted VMT than the 24-hour assignment.

Table III-1
Total VMT on the Regional Network

	Area Types					
			Inner			
	CBD	Urban	Suburban	Suburban	Rural	TOTALS
Freeways						
# of Links	22	163	158	141	69	553
Miles	5.99	67.12	99.47	117.11	103.34	393.01
Lane Miles	43.48	554.57	601.19	583.56	413.36	2,196.14
Counted VMT	689,015	10,221,248	11,824,259	6,320,893	2,924,383	31,979,798
24-Hour Model	704,630	10,784,254	12,167,028	6,533,341	3,016,423	33,205,676
TOD Model *	682,059	10,664,138	11,963,606	6,477,158	3,009,163	32,796,124
Principal Arterials						
# of Links	22	230	517	485	158	1,412
Miles	1.89	66.14	213.60	267.51	143.46	692.52
Lane Miles	10.36	336.63	856.25	954.28	466.28	2,623.76
Counted VMT	29,837	1,631,903	5,169,022	5,184,157	1,880,838	13,895,757
24-Hour Model	34,123	1,645,393	5,027,496	5,035,560	1,786,288	13,528,860
TOD Model *	33,562	1,573,696	4,853,559	4,923,970	1,755,665	13,140,452
Other Arterials						
# of Links	254	1,166	2,071	1,195	1,039	5,725
Miles	21.24	309.92	817.93	676.65	1,340.03	3,165.60
Lane Miles	156.11	1,092.90	2,487.71	1,710.25	2,742.46	8,185.51
Counted VMT	368,252	4,050,547	10,573,441	5,599,954	5,054,966	25,647,160
24-Hour Model	280,400	3,912,928	10,806,688	5,314,384	5,148,945	25,463,345
TOD Model *	286,210	3,829,432	11,133,168	5,478,075	5,090,646	25,817,531
Collectors						
# of Links	14	144	298	347	532	1,335
Miles	1.91	34.59	118.96	209.69	761.78	1,126.88
Lane Miles	7.92	80.23	260.77	443.57	1,523.59	2,316.02
Counted VMT	28,067	181,766	458,072	383,085	528,719	1,579,709
24-Hour Model	30,595	178,356	369,438	380,061	611,207	1,569,657
TOD Model *	35,969	173,270	351,831	360,124	542,094	1,463,288
TOTALS						
# of Links	312	1,703	3,044	2,168	1,798	9,025
Miles	31.03	477.71	1,249.85	1,270.86	2,348.57	5,375.48
Lane Miles	217.87	2,064.29	4,205.66	3,691.60	5,145.15	15,314.85
Counted VMT	1,115,170	16,085,464	28,024,794	17,488,090	10,388,906	73,102,424
24-Hour Model	1,049,747	16,520,931	28,370,650	17,263,346	10,562,863	73,767,537
TOD Model *	1,037,799	16,240,536	28,302,164	17,239,327	10,397,569	73,217,395

* Time-of-Day Model: Sum of four Time-of-day assignments

Table III-2
Assigned versus Counted VMT

	CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
	Area Types					
Freeways						
# of Links	22	163	158	141	69	553
Miles	5.99	67.12	99.47	117.11	103.34	393.01
Lane Miles	43.48	554.57	601.19	583.56	413.36	2,196.14
Counted VMT	689,015	10,221,248	11,824,259	6,320,893	2,924,383	31,979,798
24-Hour Model	102.3%	105.5%	102.9%	103.4%	103.1%	103.8%
TOD Model *	99.0%	104.3%	101.2%	102.5%	102.9%	102.6%
Principal Arterials						
# of Links	22	230	517	485	158	1,412
Miles	1.89	66.14	213.60	267.51	143.46	692.52
Lane Miles	10.36	336.63	856.25	954.28	466.28	2,623.76
Counted VMT	29,837	1,631,903	5,169,022	5,184,157	1,880,838	13,895,757
24-Hour Model	114.4%	100.8%	97.3%	97.1%	95.0%	97.4%
TOD Model *	112.5%	96.4%	93.9%	95.0%	93.3%	94.6%
Other Arterials						
# of Links	254	1,166	2,071	1,195	1,039	5,725
Miles	21.24	309.92	817.93	676.65	1,340.03	3,165.60
Lane Miles	156.11	1,092.90	2,487.71	1,710.25	2,742.46	8,185.51
Counted VMT	368,252	4,050,547	10,573,441	5,599,954	5,054,966	25,647,160
24-Hour Model	76.1%	96.6%	102.2%	94.9%	101.9%	99.3%
TOD Model *	77.7%	94.5%	105.3%	97.8%	100.7%	100.7%
Collectors						
# of Links	14	144	298	347	532	1,335
Miles	1.91	34.59	118.96	209.69	761.78	1,126.88
Lane Miles	7.92	80.23	260.77	443.57	1,523.59	2,316.02
Counted VMT	28,067	181,766	458,072	383,085	528,719	1,579,709
24-Hour Model	109.0%	98.1%	80.7%	99.2%	115.6%	99.4%
TOD Model *	128.2%	95.3%	76.8%	94.0%	102.5%	92.6%
TOTALS						
# of Links	312	1,703	3,044	2,168	1,798	9,025
Miles	31.03	477.71	1,249.85	1,270.86	2,348.57	5,375.48
Lane Miles	217.87	2,064.29	4,205.66	3,691.60	5,145.15	15,314.85
Counted VMT	1,115,170	16,085,464	28,024,794	17,488,090	10,388,906	73,102,424
24-Hour Model	94.1%	102.7%	101.2%	98.7%	101.7%	100.9%
TOD Model *	93.1%	101.0%	101.0%	98.6%	100.1%	100.2%

* Time-of-Day Model: Sum of four Time-of-day assignments

CUTLINE RESULTS

Table III-3 summarizes the comparisons of assigned cutline volumes to the counted cutline volumes for certain corridors in the Houston-Galveston region. The table shows the 56 cutlines, the number of links which make up that cutline, and the counted volume across the cutline. Further, it shows the percentage of the count that was assigned by both the 24-Hour Model and the Time-of-Day Model. The percentages were computed by dividing the sum of the assigned volumes on the links by the sum of the counted volumes on the same links. The Time-of-Day Model compared more favorably to counts on 30 of the 56 cutlines, while the 24-Hour Model compared more favorably to counts on 26 of the 56 cutlines.

ITERATION WEIGHTS

As may be recalled, the assignments were performed using an equilibrium assignment option in the Texas Largenet Packages (8). One of the advantages of the equilibrium option is that optimal iteration weights are computed during the assignment process. Table III-4 summarizes the resulting iteration weights for the assignments.

- The iteration weights from the time-of-day assignments are particularly interesting. More than 99 percent of the overnight traffic was assigned using Iteration 1 paths. The Iteration 1 paths are those determined using the unadjusted input link speeds. In effect, the overnight assignment is little more than an all-or-nothing assignment.
- The midday assignment assigned most of the traffic to the Iteration 1 and 2 paths.
- The peak-period assignments showed the greatest diversion to alternative paths. Since the peak periods are the most congested times, it is only logical to expect that these will get the greatest diversion to alternative routes (as reflected in the iteration weights).
- The 24-hour assignment put 21.954 percent of the trips on the Iteration 1 path. In combination, the time-of-day assignments put considerably more travel on the Iteration 1 path.
- For the 24-hour assignment, the impedance adjustments between iterations are based on the ratio of the weighted average 24-hour assigned volume to the 24-hour capacity (i.e., the 24-hour v/c ratio). For the time-of-day assignments, the impedance adjustments on a link between iterations for a given time period is effectively a

function of the average hourly v/c ratio for the link during that time period. In the overnight time periods, the average hourly v/c ratios were generally very low; and, hence, there were little changes in the impedances (i.e., congestion delays). While there are few congestion delays in overnight periods, the overnight assignments lose the desirable multi-path characteristic. It may be desirable to use a different impedance adjustment function for overnight periods (to induce multiple paths) or to use a stochastic assignment technique (if available). This may be an area for further investigation to improve time-of-day assignments.

SUMMARY OF FINDINGS

Both assignment techniques produced very similar results in terms of VMT and cutlines. When compared to counts, the time-of-day assignment produced only slightly better results than the 24-hour assignment.

Table III-3
Cutline Results

Cutline Number	Total Links	Total Counted Volume	Assigned Volume as % of Count: 24-Hour Model	Assigned Volume as % of Count: Time-of-day Model
1	8	160,957	97.1	98.5
2	10	152,741	100.8	107.4
3	11	148,200	92.6	94.4
4	9	158,800	96.1	93.3
5	6	251,372	99.3	100.8
6	5	177,627	129.2	127.1
7	7	121,158	95.9	95.3
8	5	107,187	180.9	191.4
9	3	311,393	108.7	105.8
10	5	123,685	117.0	136.9
11	7	207,565	106.1	104.8
12	7	319,111	112.4	110.6
13	7	493,046	99.1	96.2
14	8	469,470	109.5	105.2
15	7	142,073	124.0	123.5
16	3	111,224	123.5	130.4
17	7	140,021	113.6	116.6
18	9	273,043	91.1	91.4
19	6	74,733	113.4	100.9
20	9	393,260	110.5	109.2
21	4	65,669	88.7	87.7
22	5	179,496	106.4	103.5
23	2	82,230	132.6	131.4
24	2	98,390	116.3	115.4
25	6	188,924	106.8	112.2
26	5	169,788	84.4	84.2
27	4	88,797	99.1	102.7
28	2	81,435	120.3	119.9
29	7	116,937	104.4	103.3
30	6	157,850	87.8	89.9
31	5	44,720	120.0	116.7
32	3	92,872	119.0	113.9
33	3	7,400	129.2	120.4

Table III-3 (Continued)
Cutline Results

Cutline Number	Total Links	Total Counted Volume	Assigned Volume as % of Count 24-Hour Model	Assigned Volume as % of Count Time-of-Day Model
34	2	67,925	111.2	111.7
35	4	30,200	92.4	84.5
36	7	88,894	119.2	114.6
37	3	31,331	67.8	66.7
38	3	41,465	104.3	104.7
39	4	138,586	112.5	116.4
40	3	108,625	88.1	87.6
42	5	87,715	111.8	104.7
44	2	44,350	111.7	109.9
45	3	50,600	91.9	91.8
47	7	203,326	136.6	137.3
48	7	144,647	127.2	123.1
49	7	332,490	107.7	105.1
50	9	239,619	121.1	127.6
51	7	330,355	106.5	105.5
52	5	36,351	102.5	99.5
53	2	10,130	93.0	87.1
54	7	75,176	101.0	101.1
55	4	125,103	64.0	64.9
56	5	65,997	105.8	105.3
57	3	101,535	103.5	99.3
58	5	48,220	86.6	86.1
74	12	192,709	110.6	113.3
All	309	8,306,523	107.7	107.5

Table III-4
Equlibrium Assignment Iteration Weights and VMT

Iteration Weight	24-Hour Assignment	Time-of-Day Assignments			
		Morning Peak	Mid-day	Afternoon Peak	Overnight
Iteration 1	21.954	28.938	32.088	24.446	99.979
Iteration 2	15.160	6.678	34.878	11.300	0.003
Iteration 3	10.118	10.903	14.539	19.497	0.003
Iteration 4	17.974	25.619	18.468	10.358	0.007
Iteration 5	12.193	11.293	0.013	22.029	0.003
Iteration 6	22.601	16.569	0.013	12.370	0.003
Final VMT	73,767,536	12,877,960	27,806,588	18,629,597	13,903,248
% of 24-hour	100.00	17.59	37.98	25.44	18.99

IV. COMPARISON OF ASSIGNMENT RESULTS USING MICRO-LEVEL MEASURES

The evaluation of the traffic assignment models focuses on their ability to reflect reality (i.e., counted volume). Measures of how well an assignment reproduces traffic counts can be divided into two groups: macro-level measures and micro-level measures. This chapter presents the comparisons of the results using micro-level measures. The comparisons using macro-level measures are presented in Chapter III.

MICRO-LEVEL MEASURES

The macro-level measures compare aggregate measures of assigned versus counted volumes while micro-level measures focus on link-by-link differences. Three micro-level measures were used to compare the various assignment results with the counted volumes: The percent mean differences, the percent standard deviation of the differences, and the percent root-mean-square error (i.e., the percent RMSE). The links were first cross-classified by volume group and area type to compute the micro-measures. Next, the links were cross-classified by functional class and area type to compute the second set of micro-measures. The following are the computational formulas used in estimating the micro-measures for each subset of links (4):

$$Mean\ Difference\ (MD) = \frac{\sum (A_i - C_i)}{N}$$

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

$$Percent\ Mean\ Difference\ (PMD) = \left(\frac{MD}{(\sum C_i)/N}\right)100$$

$$Root\ Mean\ Square\ Error\ (RMSE) = \sqrt{\frac{\sum (A_i - C_i)^2}{(N-1)}}$$

$$Percent\ Standard\ Dev\ (PSD) = \left(\frac{SD}{(\sum C_i)/N}\right)100$$

$$Percent\ RMSE\ (\%RMSE) = \left(\frac{RMSE}{(\sum C_i)/N}\right)100$$

Where:

A_i	=	*assigned volume on link i in the subset*
C_i	=	*counted volume on link i in the subset*
N	=	*number of links in the subset being examined*

PERCENT MEAN DIFFERENCES OF THE RESULTS

The percent mean difference provides an estimate of the average error that was observed relative to the counted volumes. Table IV-1 summarizes the percent mean differences for the links in the regional network stratified by functional class and area type. In reviewing the results, it may be noted that:

- The 24-Hour Model produced slightly better results for principal arterials and other arterials while the Time-of-Day Model yielded better results for freeways and collectors. Both models overassigned freeways and under assigned the principal arterials on average.
- The 24-Hour Model produced slightly better results for the CBD, inner suburban, and suburban area types while the Time-of-Day Model produced slightly better results for the urban and rural area types. Both models underassigned the CBD on average, with the Time-of-Day Model producing slightly better overall results.

The percent mean difference results by volume group and area type are presented in Table IV-2. In reviewing the results, it may be noted that:

- Both models had a tendency for over assignment for the links with counts less than 10,000. This was not true, however, for the links in the CBD with counts less than 10,000.
- For links with counts greater than 20,000, there was a general tendency for underassignment. This was clearly the case in the CBD where, overall, both models underassigned links. For links with volumes greater than 100,000, however, both models tended toward overassignment.
- The Time-of-Day Model produced slightly better results for count volumes up to 40,000 and greater than 75,000. The 24-Hour Model produced better results for counts between 40,000 and 75,000.
- Both models overassigned links for all area types except for the CBD as stated earlier. The 24-Hour Model produced slightly better results for the CBD, inner suburban, and suburban area types; the Time-of-Day Model produced slightly better results for the urban and rural area types. Overall the Time-of-Day Model produced slightly better results.

Table IV-1
Average Percent Differences by Functional Class and Area Type

	Area Types					
	CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
Freeways						
Links	22	163	158	141	69	553
Avg. Count	114,378.6	152,112.4	118,473.1	52,695.1	28,089.6	100,176.5
24 HR Model	-0.1%	6.0%	3.7%	6.3%	3.4%	4.9%
TOD Model	-2.1%	5.0%	1.8%	5.5%	3.1%	3.6%
Principal Arterials						
Links	22	230	517	485	158	1,412
Avg. Count	15,685.2	24,241.8	24,234.5	19,856.2	14,101.1	21,464.7
24 HR Model	8.0%	3.7%	-1.0%	-2.0%	-6.6%	-0.8%
TOD Model	6.2%	-0.4%	-2.2%	-3.7%	-7.1%	-2.6%
Other Arterials						
Links	254	1,166	2,071	1,195	1,039	5,725
Avg. Count	17,070.4	12,986.3	12,884.3	8,380.8	4,340.0	10,600.1
24 HR Model	-28.3%	4.6%	4.3%	-2.3%	2.5%	0.8%
TOD Model	-31.1%	2.5%	7.7%	1.5%	2.7%	2.3%
Collectors						
Links	14	144	298	347	532	1,335
Avg. Count	14,453.0	5,118.0	3,975.2	2,055.6	788.3	2,439.4
24 HR Model	13.0%	2.6%	-12.1%	7.1%	25.0%	1.8%
TOD Model	32.0%	2.6%	-14.2%	1.8%	11.2%	-0.8%
TOTALS						
Links	312	1,703	3,044	2,168	1,798	9,025
Avg. Count	23,716.7	27,157.3	19,420.5	12,817.6	5,058.3	16,581.5
24 HR Model	-15.9%	5.2%	2.6%	0.3%	1.5%	2.0%
TOD Model	-17.8%	3.5%	3.3%	0.8%	0.8%	1.7%

Table IV-2
Average Percent Differences by Volume Group and Area Type

	Area Types CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
Count: Under 5,000						
Links	14	194	539	728	1,254	2,729
Avg. Count	2,283.9	3,320.9	2,908.5	2,357.1	1,811.4	2,283.4
24 HR Model	-35.9%	69.5%	54.3%	39.6%	26.4%	41.2%
TOD Model	-55.9%	67.8%	52.8%	37.3%	21.6%	38.1%
Count: 5,000 to 10,000						
Links	39	429	663	522	314	1,967
Avg. Count	7,660.3	7,309.2	7,376.2	7,354.1	7,167.9	7,328.1
24 HR Model	-15.1%	25.2%	14.8%	7.9%	-10.1%	10.7%
TOD Model	-7.2%	24.6%	12.0%	7.7%	-11.0%	9.6%
Count: 10,000 to 20,000						
Links	146	620	1,047	524	146	2,483
Avg. Count	14,878.4	14,410.3	14,702.6	13,917.0	14,978.8	14,490.4
24 HR Model	-18.5%	4.4%	2.5%	-8.2%	-9.1%	-1.1%
TOD Model	-20.4%	1.4%	5.3%	-4.2%	-6.7%	0.1%
Count: 20,000 to 30,000						
Links	70	200	427	201	59	957
Avg. Count	23,004.4	24,465.8	24,026.1	23,727.5	24,945.5	24,037.2
24 HR Model	-32.2%	-1.7%	-6.2%	-14.6%	-5.3%	-8.7%
TOD Model	-38.6%	-2.8%	-2.9%	-13.5%	-4.4%	-7.6%
Count: 30,000 to 40,000						
Links	21	69	151	61	20	322
Avg. Count	34,819.5	33,795.3	34,071.1	34,013.1	33,902.5	34,039.4
24 HR Model	-32.2%	-20.1%	-3.9%	-6.9%	5.7%	-9.2%
TOD Model	-32.8%	-19.2%	2.6%	-13.3%	5.4%	-7.2%
Count: 40,000 to 50,000						
Links	2	20	58	65	4	149
Avg. Count	40,000.0	42,974.7	43,351.9	44,270.6	44,225.0	43,680.5
24 HR Model	-2.4%	-16.0%	-7.7%	7.0%	4.3%	-1.9%
TOD Model	49.3%	-22.3%	-7.9%	5.7%	5.0%	-2.7%
Count: 50,000 to 75,000						
Links	1	14	31	34	1	81
Avg. Count	73,470.0	68,360.0	62,671.3	63,530.9	58,900.0	64,102.1
24 HR Model	-26.4%	-9.3%	-3.0%	5.6%	-7.7%	-1.0%
TOD Model	26.4%	-26.5%	-12.9%	5.2%	-8.3%	-7.3%
Count: 75,000 to 100,000						
Links	3	8	20	22	0	53
Avg. Count	92,333.3	94,906.3	88,306.9	85,463.6	0.0	88,350.7
24 HR Model	13.7%	25.2%	4.9%	11.7%	0.0%	11.4%
TOD Model	-3.0%	14.7%	-0.5%	11.8%	0.0%	6.8%
Count: 100,000 and above						
Links	16	149	108	11	0	284
Avg. Count	132,791.3	159,287.4	144,787.3	107,222.9	0.0	150,263.9
24 HR Model	0.9%	5.8%	3.8%	0.5%	0.0%	4.7%
TOD Model	-1.1%	5.0%	2.2%	1.3%	0.0%	3.6%
TOTALS						
Links	312	1,703	3,044	2,168	1,798	9,025
Avg. Count	23,716.7	27,157.3	19,420.5	12,817.6	5,058.3	16,581.5
24 HR Model	-15.9%	5.2%	2.6%	0.3%	1.5%	2.0%
TOD Model	-17.8%	3.5%	3.3%	0.8%	0.8%	1.7%

PERCENT STANDARD DEVIATION OF THE DIFFERENCES

Table IV-3 summarizes the percent standard deviation of the differences for the links stratified by functional class and area type. In reviewing the results of the table, it may be observed that:

- The higher level facilities such as freeways and principal arterials had generally lower percent differences than the other lower level facilities. This is not surprising since the percent standard deviation tends to generally decrease with increases in the counted volumes and because the higher level facilities such as freeways and principal arterials tend to carry the higher volumes.
- The percent standard deviation of the differences was fairly consistent for both models. The Time-of-Day Model, however, had a slightly higher percent standard deviation of the differences for all functional classes and area types. The 24-Hour Model produced slightly better results overall.

Table IV-4 summarizes the percent standard deviation of the differences for the links stratified by volume group and area type. In reviewing the results of the table, it may be observed that:

- As expected, the percent standard deviation tends to generally decrease with increases in counted volumes.
- Again, the percent standard deviation of the differences was fairly consistent for both models. In addition, as with the area types and functional classes, the percent standard deviation of the differences was slightly higher for the Time-of-Day Model for all volume count categories. The 24-Hour Model produced slightly better results overall.

Table IV-3
Percent Standard Deviation by Functional Class and Area Type

	Area Types					
	CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
Freeways						
Links	22	163	158	141	69	553
Avg. Count	114,378.6	152,112.4	118,473.1	52,695.1	28,089.6	100,176.5
24 HR Model	17.3%	14.1%	14.4%	19.9%	9.6%	16.4%
TOD Model	17.5%	16.4%	16.0%	20.8%	9.9%	18.4%
Principal Arterials						
Links	22	230	517	485	158	1,412
Avg. Count	15,685.2	24,241.8	24,234.5	19,856.2	14,101.1	21,464.7
24 HR Model	50.2%	42.8%	34.1%	30.5%	25.7%	35.4%
TOD Model	66.8%	46.2%	37.3%	36.2%	28.5%	39.4%
Other Arterials						
Links	254	1,166	2,071	1,195	1,039	5,725
Avg. Count	17,070.4	12,986.3	12,884.3	8,380.8	4,340.0	10,600.1
24 HR Model	47.5%	62.4%	48.9%	55.0%	56.4%	57.7%
TOD Model	55.8%	67.3%	56.0%	61.2%	59.8%	64.4%
Collectors						
Links	14	144	298	347	532	1,335
Avg. Count	14,453.0	5,118.0	3,975.2	2,055.6	788.3	2,439.4
24 HR Model	33.2%	87.0%	90.4%	125.6%	136.2%	112.4%
TOD Model	71.0%	101.4%	101.2%	132.8%	134.6%	130.9%
TOTALS						
Links	312	1,703	3,044	2,168	1,798	9,025
Avg. Count	23,716.7	27,157.3	19,420.5	12,817.6	5,058.3	16,581.5
24 HR Model	40.0%	38.8%	38.5%	41.9%	45.7%	43.4%
TOD Model	46.0%	42.9%	43.0%	46.6%	48.6%	48.2%

Table IV-4
Percent Standard Deviation by Volume Group and Area Type

		Area Types				
	CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
Count: Under 5,000						
Links	14	194	539	728	1,254	2,729
Avg. Count	2,283.9	3,320.9	2,908.5	2,357.1	1,811.4	2,283.4
24 HR Model	52.3%	148.0%	155.4%	118.8%	96.1%	135.4%
TOD Model	55.1%	152.6%	164.3%	130.6%	103.1%	144.0%
Count: 5,000 to 10,000						
Links	39	429	663	522	314	1,967
Avg. Count	7,660.3	7,309.2	7,376.2	7,354.1	7,167.9	7,328.1
24 HR Model	55.4%	79.5%	74.9%	53.7%	36.4%	66.7%
TOD Model	71.8%	83.6%	76.0%	61.6%	39.1%	70.4%
Count: 10,000 to 20,000						
Links	146	620	1,047	524	146	2,483
Avg. Count	14,878.4	14,410.3	14,702.6	13,917.0	14,978.8	14,490.4
24 HR Model	53.8%	59.9%	42.4%	38.8%	23.9%	47.1%
TOD Model	63.6%	65.3%	50.3%	43.7%	25.6%	53.4%
Count: 20,000 to 30,000						
Links	70	200	427	201	59	957
Avg. Count	23,004.4	24,465.8	24,026.1	23,727.5	24,945.5	24,037.2
24 HR Model	38.0%	44.4%	30.4%	27.4%	13.7%	33.9%
TOD Model	43.6%	47.8%	35.9%	31.1%	16.4%	38.6%
Count: 30,000 to 40,000						
Links	21	69	151	61	20	322
Avg. Count	34,819.5	33,795.3	34,071.1	34,013.1	33,902.5	34,039.4
24 HR Model	29.9%	29.7%	26.7%	18.1%	9.1%	27.1%
TOD Model	37.7%	31.9%	34.0%	21.0%	9.7%	32.7%
Count: 40,000 to 50,000						
Links	2	20	58	65	4	149
Avg. Count	40,000.0	42,974.7	43,351.9	44,270.6	44,225.0	43,680.5
24 HR Model	0.0%	21.5%	24.6%	19.8%	6.8%	23.2%
TOD Model	0.0%	20.9%	23.9%	24.8%	6.8%	25.9%
Count: 50,000 to 75,000						
Links	1	14	31	34	1	81
Avg. Count	73,470.0	68,360.0	62,671.3	63,530.9	58,900.0	64,102.1
24 HR Model	0.0%	24.3%	21.5%	20.5%	0.0%	22.1%
TOD Model	0.0%	13.6%	20.2%	20.5%	0.0%	22.9%
Count: 75,000 to 100,000						
Links	3	8	20	22	0	53
Avg. Count	92,333.3	94,906.3	88,306.9	85,463.6	0.0	88,350.7
24 HR Model	4.6%	16.5%	16.7%	15.7%	0.0%	17.1%
TOD Model	22.3%	20.7%	18.2%	17.1%	0.0%	19. 1%
Count: 100,000 and above						
Links	16	149	108	11	0	284
Avg. Count	132,791.3	159,287.4	144,787.3	107,222.9	0.0	150,263.9
24 HR Model	15.6%	13.2%	13.4%	9.7%	0.0%	13.4%
TOD Model	15.6%	15.7%	14.8%	10.3%	0.0%	15.4%
TOTALS						
Links	312	1,703	3,044	2,168	1,798	9,025
Avg. Count	23,716.7	27,157.3	19,420.5	12,817.6	5,058.3	16,581.5
24 HR Model	40.0%	38.8%	38.5%	41.9%	45.7%	43.4%
TOD Model	46.0%	42.9%	43.0%	46.6%	48.6%	48.2%

PERCENT ROOT MEAN SQUARE ERROR

The percent root mean square error is a micro-measure which is similar to the percent standard deviation in that it also attempts to provide a measure of the relative dispersion of the estimates relative to the observed counts. Table IV-5 summarizes the percent RMSE for links stratified by functional class and area type. Table IV-6 summarizes the percent RMSE for the links stratified by volume group and area type. The following observations can be made:

- As expected, links in the functional classes which tend to carry the higher volumes tend to have the lower percent RMSE results. This was also the case for the links in the higher volume categories. As with the percent standard deviation results, percent RMSE decreased as volume increased.
- As was the case with the percent standard deviation of the differences, the percent RMSE results were fairly consistent for both models.
- The 24-Hour Model produced slightly better results for all area types and all count volume categories with the exception of the 53 links in the 75,000 to 100,000 range.

Table IV-5
Percent RMSE by Functional Classification and Area Type

	Area Types					
	CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
Freeways						
Links	22	163	158	141	69	553
Avg. Count	114,378.6	152,112.4	118,473.1	52,695.1	28,089.6	100,176.5
24 HR Model	17.3%	15.3%	14.9%	20.9%	10.2%	17.1%
TOD Model	17.6%	17.2%	16.1%	21.5%	10.4%	18.7%
Principal Arterials						
Links	22	230	517	485	158	1,412
Avg. Count	15,685.2	24,241.8	24,234.5	19,856.2	14,101.1	21,464.7
24 HR Model	50.8%	42.9%	34.1%	30.6%	26.5%	35.4%
TOD Model	67.1%	46.2%	37.4%	36.3%	29.4%	39.5%
Other Arterials						
Links	254	1,166	2,071	1,195	1,039	5,725
Avg. Count	17,070.4	12,986.3	12,884.3	8,380.8	4,340.0	10,600.1
24 HR Model	55.3%	62.6%	49.1%	55.1%	56.5%	57.7%
TOD Model	63.9%	67.3%	56.5%	61.2%	59.9%	64.5%
Collectors						
Links	14	144	298	347	532	1,335
Avg. Count	14,453.0	5,118.0	3,975.2	2,055.6	788.3	2,439.4
24 HR Model	35.9%	87.0%	91.2%	125.8%	138.5%	112.5%
TOD Model	78.4%	101.5%	102.3%	132.8%	135.1%	130.9%
TOTALS						
Links	312	1,703	3,044	2,168	1,798	9,025
Avg. Count	23,716.7	27,157.3	19,420.5	12,817.6	5,058.3	16,581.5
24 HR Model	43.0%	39.1%	38.6%	41.9%	45.7%	43.4%
TOD Model	49.4%	43.0%	43.2%	46.6%	48.6%	48.2%

Table IV-6
Percent RMSE by Volume Group and Area Type

		Area Types				
	CBD	Urban	Inner Suburban	Suburban	Rural	TOTALS
Count: Under 5,000						
Links	14	194	539	728	1254	2,729
Avg. Count	2,283.9	3,320.9	2,908.5	2,357.1	1,811.4	2,283.4
24 HR Model	64.2%	163.6%	164.6%	125.2%	99.7%	141.5%
TOD Model	80.0%	167.0%	172.6%	135.9%	105.3%	149.0%
Count: 5,000 to 10,000						
Links	39	429	663	522	314	1,967
Avg. Count	7,660.3	7,309.2	7,376.2	7,354.1	7,167.9	7,328.1
24 HR Model	57.5%	83.4%	76.3%	54.3%	37.8%	67.6%
TOD Model	72.1%	87.1%	76.9%	62.1%	40.6%	71.1%
Count: 10,000 to 20,000						
Links	146	620	1047	524	146	2,483
Avg. Count	14,878.4	14,410.3	14,702.6	13,917.0	14,978.8	14,490.4
24 HR Model	56.9%	60.0%	42.5%	39.6%	25.6%	47.1%
TOD Model	66.8%	65.3%	50.6%	43.9%	26.5%	53.4%
Count: 20,000 to 30,000						
Links	70	200	427	201	59	957
Avg. Count	23,004.4	24,465.8	24,026.1	23,727.5	24,945.5	24,037.2
24 HR Model	49.9%	44.4%	31.0%	31.0%	14.7%	35.1%
TOD Model	58.4%	47.9%	36.0%	34.0%	17.0%	39.4%
Count: 30,000 to 40,000						
Links	21	69	151	61	20	322
Avg. Count	34,819.5	33,795.3	34,071.1	34,013.1	33,902.5	34,039.4
24 HR Model	44.5%	36.0%	27.0%	19.4%	10.8%	28.6%
TOD Model	50.5%	37.3%	34.1%	24.9%	11.2%	33.5%
Count: 40000 to 50000						
Links	2	20	58	65	4	149
Avg. Count	40,000.0	42,974.7	43,351.9	44,270.6	44,225.0	43,680.5
24 HR Model	3.5%	27.0%	25.8%	21.0%	8.4%	23.3%
TOD Model	69.7%	31.0%	25.2%	25.5%	8.9%	26.1%
Count: 50,000 to 75,000						
Links	1	14	31	34	1	81
Avg. Count	73,470.0	68,360.0	62,671.3	63,530.9	58,900.0	64,102.1
24 HR Model	0.0%	26.2%	21.7%	21.3%	0.0%	22.1%
TOD Model	0.0%	30.7%	24.1%	21.2%	0.0%	24.0%
Count: 75,000 to 100,000						
Links	3	8	20	22	0	53
Avg. Count	92,333.3	94,906.3	88,306.9	85,463.6	0.0	88,350.7
24 HR Model	17.4%	31.6%	17.4%	19.7%	0.0%	20.6%
TOD Model	22.6%	26.0%	18.2%	20.9%	0.0%	20.3%
Count: 100,000 and above						
Links	16	149	108	11	0	284
Avg. Count	132,791.3	159,287.4	144,787.3	107,222.9	0.0	150,263.9
24 HR Model	15.6%	14.4%	13.9%	9.7%	0.0%	14.2%
TOD Model	15.6%	16.5%	15.0%	10.4%	0.0%	15.9%
TOTALS						
Links	312	1,703	3,044	2,168	1,798	9,025
Avg. Count	23,716.7	27,157.3	19,420.5	12,817.6	5,058.3	16,581.5
24 HR Model	43.0%	39.1%	38.6%	41.9%	45.7%	43.4%
TOD Model	49.4%	43.0%	43.2%	46.6%	48.6%	48.2%

SUMMARY OF FINDINGS

It was anticipated that the use of multiple time-of-day assignments would produce significantly better results than the traditional 24-hour assignments. The comparison of the assignment results from the two techniques to the count-based estimates did not support this expectation. Using the macro-level measures, the time-of-day assignments produced only slightly better results than the traditional 24-hour. The micro measures indicated the 24-hour produced somewhat better results relative to the count estimates. Neither assignment technique emerged as clearly better in replicating the count-based volume estimates. These results suggest that the users could feel equally comfortable in estimating 24-hour volumes for the Houston-Galveston region from either time-of-day assignments or from a 24-hour assignment.

The review of the iteration weights for the time-of-day assignments suggests that there may be some potential improvements to be achieved in the overnight and midday assignments. To get more diversion to alternative reasonable paths, a stronger impedance adjustment function may be needed that somewhat overstates the impact of congestion delays. While this may produce better assignment results in off-peak periods, it will likely produce less realistic speeds. This may be in conflict with the goal of the work planned under Task 5 of this study.

V. EMISSIONS ANALYSES

In an effort to quantify the impact on emissions estimates which result from using the two different approaches for developing 24-hour assignment volume estimates, a new series of programs developed by TTI was used. This new series of programs was developed by TTI to facilitate the application of EPA's MOBILE5a program in estimating mobile source emissions. This new series includes the programs POLFAC5A, PREPIN, and IMPSUM (5).

OVERVIEW OF EMISSION ESTIMATION METHODOLOGY

The methodology and software used in developing the estimates are described below. The three programs used for computing the mobile source emissions for this study are:

PREPIN — The PREPIN program was developed for urban areas where time-of-day assignments and speeds are not available for air quality analyses. The program inputs a 24-hour assignment and applies the needed seasonal adjustment factors. The time-of-day factors are applied to the seasonally adjusted 24-hour assignment results to estimate the directional time-of-day travel. The PREPIN program allows the analyst to factor a 24-hour assignment (produced by the Texas Large Network Assignment Package) to estimate the vehicle miles of travel (VMT). For example, a 24-hour assignment can be factored to represent time periods: the morning peak hour, the afternoon peak hour, the midday travel (i.e., the travel between the morning and afternoon peak hours), and the overnight travel (i.e., the typical portion of the daily travel occurring between the afternoon peak hour and the morning peak hour). This example would require four applications of PREPIN (i.e., an application for each time period). The Houston-Galveston speed models are used to estimate the operational time-of-day speeds by direction in the links. Special intrazonal links are defined, and the VMT and speeds for intrazonal trips are estimated. These VMT and speeds by link are subsequently input to the IMPSUM program for the application of MOBILE5a emission factors.

POLFAC5A The POLFAC5A program is used to apply the EPA's MOBILE5a program to obtain the emission FACTORS (rates). The MOBILE5a emission factors are obtained for eight vehicle types and 63 speeds (i.e., 8 x 63 = 504) for each pollution type for each county. Three pollution types being computed: VOC, CO and NOx. Hence, for a given county there are 1,512 emission factors. These emission factors are output to an ASCII file for subsequent input to the IMPSUM program. The POLFAC5A program is applied for each time-of-day period being used. These time-of-day emission factors are applied using the IMPSUM program to time-of-day VMT estimates by link to estimate emissions.

IMPSUM The IMPSUM program applies the emission rates (obtained from POLFAC5A) and VMT mixes to the time-of-day VMT and speed estimates to estimate the emissions. The basic inputs to IMPSUM are:

1. Data specifying the number of counties in the region and their names.
2. Names of roadway types used in the study. These roadway types are used to summarize the emission results.
3. VMT mix by county and roadway type.
4. MOBILE5a emission factors developed using POLFAC5A by county.
5. Specifications of the units for reporting emissions (grams, pounds, or tons).
6. Abbreviated assignment results by link input for the subject time period. The PREPIN program allows the user to estimate VMT and speed on each link by time period. For each link, the following information is input to IMPSUM: county number, roadway type number, VMT on link, operational speed estimate, and link distance.

Using these input data, the VMT for each link is stratified by the eight vehicle types and the MOBILE5a emission factors are applied to estimate the mobile source emissions for that link. The emissions for each county and emission type are reported by both roadway type and vehicle type (i.e., cross-classified by roadway type and vehicle type). The following time-of-day periods were used in the Houston-Galveston region for this study:

1. Morning Peak Hour: 6:30 a.m. - 8:30 a.m.
2. Mid-day: 8:30 a.m. - 3:30 p.m.
3. Afternoon Peak Hour: 3:30 p.m. - 6:30 p.m.
4. Overnight: 6:30 p.m. - 6:30 a.m.

FACTORING 24-HOUR ASSIGNMENTS

The 24-hour assignments were factored using two inputs to the PREPIN program. The two inputs are the time period adjustment factors and the directional split factors. Both of these sets of factors were developed from the Time-of-day assignments. In the Time-of-Day Model, the 24-hour production-to-attraction trip table was factored by trip purpose. Four separate equilibrium assignments were then performed as discussed in Chapter II. The time period adjustment factors are given in Tables V-1, V-2, V-3, and V-4, and are stratified by functional class and area type.

Table V-1
Time-of-Day Assignment Factors - AM Peak

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.1783	0.1737	0.1827	0.1829	0.1397
Principal Arterials	0.1873	0.1762	0.1714	0.1782	0.1640
Other Arterials	0.1612	0.1766	0.1791	0.1791	0.1718
Collector/Local	0.1545	0.1735	0.1816	0.1786	0.1862

Table V-2
Time-of-Day Assignment Factors - Midday

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.3901	0.3921	0.3750	0.3659	0.3890
Principal Arterials	0.4204	0.4069	0.3849	0.3756	0.3819
Other Arterials	0.4353	0.4075	0.3738	0.3700	0.3693
Collector/Local	0.4400	0.4114	0.3745	0.3679	0.3519

Table V-3
Time-of-Day Assignment Factors - PM Peak

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.2534	0.2479	0.2553	0.2542	0.2422
Principal Arterials	0.2699	0.2585	0.2554	0.2532	0.2481
Other Arterials	0.2385	0.2588	0.2625	0.2566	0.2522
Collector/Local	0.2313	0.2554	0.2640	0.2570	0.2566

Table V-4
Time-of-Day Assignment Factors - Overnight

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.1782	0.1863	0.1870	0.1970	0.2292
Principal Arterials	0.1225	0.1584	0.1884	0.1930	0.2060
Other Arterials	0.1650	0.1571	0.1847	0.1943	0.2067
Collector/Local	0.1742	0.1598	0.1799	0.1965	0.2053

Tables V-5, V-6, V-7, and V-8 show the directional split factors for the four time periods. These factors represent the typical hourly directional split in the peak direction. They are stratified by functional class and area type.

Table V-5
Directional Split Factors - AM Peak

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.5932	0.6163	0.6668	0.7101	0.6729
Principal Arterials	0.8348	0.7186	0.6558	0.6443	0.6623
Other Arterials	0.7422	0.7003	0.6516	0.6672	0.6885
Collector/Local	0.7560	0.7229	0.6846	0.7040	0.7420

Table V-6
Directional Split Factors - Midday

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.5061	0.5125	0.5156	0.5286	0.5228
Principal Arterials	0.5811	0.6011	0.5265	0.5223	0.5366
Other Arterials	0.5343	0.5682	0.5252	0.5229	0.5276
Collector/Local	0.5293	0.5398	0.5318	0.5230	0.5275

Table V-7
Directional Split Factors - PM Peak

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.5669	0.5862	0.6168	0.6381	0.5828
Principal Arterials	0.7967	0.6621	0.6087	0.5913	0.5888
Other Arterials	0.6921	0.6354	0.5999	0.6065	0.6102
Collector/Local	0.7102	0.6616	0.6073	0.6271	0.6363

Table V-8
Directional Split Factors - Overnight

Functional Class	Area Type				
	CBD	Urban	Inner Suburban	Suburban	Rural
Freeways	0.5113	0.5168	0.5102	0.5089	0.5046
Principal Arterials	0.5501	0.6024	0.5337	0.5143	0.5138
Other Arterials	0.5563	0.5713	0.5329	0.5258	0.5129
Collector/Local	0.5591	0.5489	0.5392	0.5340	0.5276

EMISSION ESTIMATES

The MOBILE5a program was used to compute the mobile source emissions rates for this study. The MOBILE5a program was applied using the POLFAC5A program to estimate the emission factors by speed for each of the four time-of-day periods (i.e., AM Peak Hour, Midday, PM Peak Hour, and Overnight). This was done for both the 24-Hour Model and Time-of-Day Model.

The POLFAC5A program is one of a series of programs developed by the Texas Transportation Institute to facilitate the computation of mobile source emissions. The POLFAC5A program is used to apply MOBILE5a to obtain emission factors. The emission factors are obtained for three pollution types for each county and the region for all four time periods. The three pollution types computed areVOC, CO, and NOx. The POLFAC5A program was applied to the four time-of-day periods for both the traditional 24-Hour Model and the Time-of-Day Model. These emission factors are then output to an ASCII file for subsequent input into the IMPSUM program.

Emission estimates were then computed using the emission factors previously discussed and the IMPSUM program. The IMPSUM program uses emission factors obtained from POLFAC5A, the user-estimated VMT mixes, and the VMT/speed estimates to compute the emissions by county. The results for each type of emission were stratified by county and roadway type. The regional totals are shown by time period in Tables V-9, V-10, V-11, and V-12, and are stratified by area type. The overall totals are shown in Table V-13.

For the AM Peak time period, the 24-Hour Model resulted in approximately 2 percent more VMT and VHT. While the speeds were nearly identical, the emissions estimates for both VOC and CO were 1.89 percent and 1.83 percent higher for the 24-Hour Model. Estimates for NOx were higher for the 24-Hour Model as well. These results are shown in Table V-9.

Table V-9
Regional Totals - AM Peak

	Type of Assignment		Absolute	Percent
	Traditional 24-Hour	Time-of-Day	Difference	Difference
Total VMT	14,394,061.30	14,117,813.66	276,247.64	1.92
Total VHT	436,147.92	427,903.32	8,244.60	1.89
Average Speed	33.00	32.99	0.01	0.03
Tons of VOC	25.09	24.62	0.47	1.89
Tons of CO	279.70	274.59	5.12	1.83
Tons of NOx	52.33	51.17	1.16	2.23

In the midday time period, the assigned VMT was 0.18 percent higher for the 24-Hour Model while the VHT was 1.50 percent lower. The average speeds were less than two percent different, with the 24-Hour Model speed being higher. The estimates for both VOC and CO were slightly higher for the Time-of-Day Model and the estimates for NOx were slightly higher for the 24-Hour Model. These results are shown in Table V-10.

Table V-10
Regional Totals - Midday

	Type of Assignment		Absolute	Percent
	Traditional 24-Hour	Time-of-Day	Difference	Difference
Total VMT	31,043,638.40	30,989,199.89	54,438.51	0.18
Total VHT	813,996.75	826,184.05	(12,187.31)	(1.50)
Average Speed	38.14	37.51	0.63	1.65
Tons of VOC	54.56	54.97	(0.42)	0.76
Tons of CO	608.88	611.74	(2.86)	(0.47)
Tons of NOx	126.47	125.80	0.68	0.53

For the PM Peak time period, the difference in assigned VMT was less than 1 percent between the two models. The VHT for the time period was virtually identical. The difference in speeds was again less than one percent with the 24-Hour Model speed being higher. The emission estimates for all three pollutants were slightly higher for the 24-Hour Model. These results are shown in Table V-11.

Table V-11
Regional Totals - PM Peak

	Type of Assignment		Absolute	Percent
	Traditional 24-Hour	Time-of-Day	Difference	Difference
Total VMT	20,832,561.19	20,642,536.43	190,024.76	0.91
Total VHT	600,448.83	600,407.13	41.70	0.01
Average Speed	34.69	34.38	0.31	0.91
Tons of VOC	38.67	38.55	0.12	0.31
Tons of CO	412.39	411.36	1.03	0.25
Tons of NOx	75.02	74.19	0.84	1.11

In the Overnight time period, the assigned VMT for the 24-Hour Model was only slightly higher than that of the Time-of-Day Model. The VHT was slightly less for the Time-of-Day Model. The speeds were slightly higher in the 24-Hour Model and the emission estimates for VOC, CO, and NOx were virtually identical. These results are shown in Table V-12.

Table V-12
Regional Totals - Overnight

	Type of Assignment		Absolute	Percent
	Traditional 24-Hour	Time-of-Day	Difference	Difference
Total VMT	15,502,068.70	15,449,037.91	53,030.79	0.34
Total VHT	395,924.23	397,327.26	(1,403.03)	(0.35)
Average Speed	39.15	38.88	0.27	0.69
Tons of VOC	23.50	23.52	(0.02)	(0.08)
Tons of CO	277.09	277.11	(0.02)	(0.01)
Tons of NOx	60.30	60.00	0.29	0.49

Overall, both the 24-Hour Model and the Time-of-Day Model yielded similar results. The VMT, VHT, and speeds were all within 1 percent of each other. The emission estimates for all three pollutants were within one percent of each other as well. These results are shown in Table V-13.

Table V-13
Overall Regional Totals

	Type of Assignment		Absolute	Percent
	Traditional 24-Hour	Time-of-Day	Difference	Difference
Total VMT	81,772,329.59	81,198,587.89	573,741.70	0.70
Total VHT	2,246,517.72	2,251,821.76	(5,304.04)	(0.24)
Average Speed	36.40	36.06	0.34	0.94
Tons of VOC	141.82	141.66	0.16	0.11
Tons of CO	1,578.06	1,574.79	3.27	0.21
Tons of NOx	314.13	311.16	2.97	0.95

SUMMARY OF FINDINGS

Both assignment techniques produced very similar emission estimates. Since the assignment results were close, it was reasonable to expect that the emission estimates would also be close. The minor differences observed generally correlate to the differences in the VMT estimates. The differences are of sufficient size to suggest that a consistent assignment technique be employed to compare alternatives so that differences in the emission results are attributable to the differences in the alternatives and not to differences in the assignment methodologies. Neither assignment technique emerged as the better approach for developing emission estimates.

VI. DEVELOPMENT OF PROPOSED IMPEDANCE ADJUSTMENT FUNCTION

The speed estimates currently used in the capacity restraint assignments are not reflective of operational speeds. Post-assignment speed models have been used in nonattainment areas to estimate speeds for the emissions analyses. The impedance adjustment function (sometimes referred to as a volume delay function) which is used in most Texas urban areas was implemented in the Texas Package in 1979. It is a variation of the classic BPR impedance adjustment function. Using the Texas function, the link impedance is adjusted based on the link's weighted average v/c ratio. The adjusted impedance is then used to estimate the minimum paths for the next iteration of the capacity restraint procedure.

With the implementation of the equilibrium assignment procedures, the ASSIGN SELF-BALANCING and PEAK CAPACITY RESTRAINT routines were modified to provide the option of applying user-supplied impedance adjustment functions rather the the Texas impedance adjustment function. While this option has been available for some time, no work has been programmed to develop improved impedance adjustment functions. The work performed under Task 5 of this study was the first effort to investigate alternative impedance adjustment functions for use in the Texas Package. Under Task 5, TTI investigated and developed alternative impedance adjustment functions which will likely produce more realistic speed results within the assignment process for time-of-day assignments.

DEVELOPMENT OF PROPOSED CURVE

In the Texas Largenet Package (similar to the TRANPLAN software), the impedance adjustment function can be specified in graphical form as a series of points. This is the approach adopted for the development of the proposed impedance adjustment functions.

For the COAST study (10, 5), TTI developed simplified versions of the Houston-Galveston speed models. These simplified models were prepared for input to the PREPIN routine to estimate post- assignment link speeds. The separate models were developed for freeways, principal arterials, other arterials, and collectors by area type. In the assignment software, the impedance adjustment functions can vary only by functional class and not by area type (9). Hence the impedance adjustment functions developed under Task 5 of this study are a further simplification of the "simplified models" developed for the COAST study.

The speed data for estimating the proposed impedance adjustment functions were developed using the detailed Houston-Galveston speed model. This model is described in the paper "Implementation and Validation of Speed Models for the Houston-Galveston Region" (3, 4). To capture the impacts of the 65 mph speed limits on rural interstates, a more recent network than the 1985 networks was obtained. The 1993 highway network for the Houston-Galveston region was used to develop the estimated speeds for estimating the impedance adjustment functions.

Traditionally, TxDOT has coded highway networks using 24-hour speeds. These 24-hour speeds are used to estimate the zone-to-zone travel times for use in trip distribution. Unfortunately these speeds are only loosely related to the actual operational speeds which vary throughout the day. To estimate operational speeds as a part of the assignment process, it will be necessary to prepare a second set of link data with freeflow speeds coded in the link data rather than 24-hour speeds. Since the proposed procedure is for time-of-day assignments, the freeflow speeds can be defined as a part of the time-of-day speed/capacity look-up tables. These time-of-day networks will need to be in the link data format for the PEAK ASSEMBLE NETWORK routine in the Texas Largenet Package. Table VI-1 lists the average estimated freeflow speeds by area type and functional group from the 1993 network.

Table VI-1
Average Estimated Freeflow Speeds

Area Types	Freeways	Principal Arterials	Other Arterials	Collectors
CBD	57.72	25.94	25.52	23.64
Urban	57.84	27.82	26.43	24.67
Inner Suburban	57.85	33.28	29.65	23.35
Suburban	58.63	40.44	37.31	33.24
Rural	62.65	55.09	54.90	50.44

The detailed Houston-Galveston speed model was applied to estimate the directional speeds on each link for v/c ratios ranging from 0.0 to 1.0 in increments of 0.05 (i.e., v/c ratios of 0.00, 0.05, 0.10, 0.15, ..., 0.90, 0.95, and 1.00). In essence 21 speed estimates were developed for each link. From these results, the weighted average speeds for each of the 21 v/c ratios for each of the four functional groups were computed. The average 24-hour speed by functional group was also computed. Table VI-2 summarizes the number of links used in estimating the data for each functional group and the average 24-hour speeds. The average estimated speeds at a v/c ratio of 0.00 (i.e., essentially the estimated freeflow speed) and at a v/c ratio of 1.00 (i.e., essentially the LOS E speed) are also presented in the table.

Table VI-2
Average 24-hour Speeds and
Estimated Operational Speeds

	Freeways	Principal Arterials	Other Arterials	Collectors
Number of links	716	1,443	6,135	1,387
Average 24-hour Speeds	50.58	36.91	36.65	28.76
Average Estimated Freeflow Speeds	57.93	37.42	35.77	34.83
Average Estimated LOS E Speeds (i.e., at V/C=1)	41.23	29.34	28.40	28.29

The impedance adjustment values for v/c ratios between 0.0 and 1.00 can be computed by dividing the average estimated speed at a given v/c ratio value by the average input speed. These results are summarized in Table VI-3.

Since traffic assignments can produce v/c ratios greater than 1.0, a model extension similar to that used in the Houston-Galveston speed models is used. The extension is based on the well-known BPR model. For links with a v/c ratio greater than 1.0, the following model extension is used to estimate the link's impedance adjustment:

$$F_{V/C} = F_{1.0} * ((1.0 + (0.15 * (V/C)^4))/1.15)$$

Where:

$F_{V/C}$ = estimated impedance adjustment factor for the forecasted v/c ratio greater than 1.0. The impedance adjustment factor is aplied to the link's freeflow impedance to estimate the congested impedance.

$F_{1.0}$ = estimated LOS E impedance adjustment factor for the v/c ratio equal to 1.0.

V/C = The forecasted weighted average v/c ratio on the link from the preceding iterations.

The computed impedance adjustment factors for v/c ratios from 1.05 to 2.00 are also summarized in Table VI-3. For comparative purposes, comparable impedance adjustment factors were computed using the traditional BPR impedance adjustment function and are included in Table VI-3.

The proposed impedance adjustment curves used in conjunction with good freeflow speeds are expected to provide better estimates of operational speeds from the time-of-day assignments. Unfortunately, it is not clear what impact this will have on assignment results. The assignment analyses in Chapter IV suggest that the use of these curves would not likely improve the off-peak time-of-day assignments. Further research would be desirable to investigate this and make recommendations.

RECOMMENDATIONS

The proposed impedance adjustment functions were developed for use with time-of-day assignments like those performed in this study. These curves were designed for application with estimated freeflow speeds. These curves were developed for application in the time-of-day assignments in the Houston-Galveston region. The transferability (or portability) of these curves for use in other urban areas is unknown.

These proposed curves have not been tested. While they can be expected to produce reasonable speed estimates for a given v/c ratio, it is not clear what impact they will have on assignment results. As may be noted in Table IV-3, the curves are relatively flat for v/c ratios up to about 0.70. It is recommended that the proposed curve be tested and evaluated in terms of both the speed estimates and the assignment results.

In analyzing the assignment results, it was noted that the overnight assignment was essentially an all-or-nothing assignment. Since the v/c ratios will also be low using the proposed curves, it is not likely that this will significantly improve these assignments. It may be that the best approach is to develop impedance adjustment functions with an objective of better replicating observed volumes. A post-assignment speed model continues to be used to estimate the operational speeds for these time periods.

For air quality analysis, the speed model options implemented in the PREPIN software allow the use of models that vary by both functional class and area type. In current assignment model software, the impedance adjustment functions can vary only by functional class. Until it is demonstrated that the proposed curves produce VMT and speed results are good as those developed using the current procedures, the implementation of the proposed functions for air quality analyses cannot be recommended.

Table VI-3
Estimated Impedance Adjustment Curves For Houston-Galveston Application

V/C	Freeways	Principal Arterials	Other Arterials	Collectors	Traditional BPR
.00	1.00000	1.00000	1.00000	1.00000	1.00000
.05	1.00002	1.00001	1.00001	1.00000	1.00000
.10	1.00004	1.00003	1.00003	1.00000	1.00002
.15	1.00008	1.00006	1.00007	1.00000	1.00008
.20	1.00013	1.00009	1.00010	1.00001	1.00024
.25	1.00030	1.00021	1.00023	1.00002	1.00059
.30	1.00046	1.00033	1.00036	1.00003	1.00122
.35	1.00075	1.00054	1.00059	1.00004	1.00225
.40	1.00105	1.00075	1.00082	1.00006	1.00384
.45	1.00144	1.00102	1.00112	1.00008	1.00615
.50	1.00182	1.00130	1.00142	1.00010	1.00938
.55	1.00220	1.00156	1.00171	1.00012	1.01373
.60	1.00259	1.00184	1.00202	1.00015	1.01944
.65	1.00282	1.00201	1.00220	1.00016	1.02678
.70	1.00308	1.00219	1.00241	1.00017	1.03602
.75	1.02005	1.01420	1.01559	1.00111	1.04746
.80	1.03765	1.02652	1.02915	1.00205	1.06144
.85	1.08571	1.05956	1.06568	1.00448	1.07830
.90	1.13822	1.09466	1.10473	1.00690	1.09842
.95	1.20956	1.14073	1.15640	1.00988	1.12218
1.00	1.40504	1.25829	1.29040	1.01655	1.15000
1.05	1.44454	1.29366	1.32667	1.04512	1.18233
1.10	1.49010	1.33446	1.36851	1.07808	1.21962
1.15	1.54231	1.38122	1.41646	1.11586	1.26235
1.20	1.60180	1.43450	1.47110	1.15890	1.31104
1.25	1.66921	1.49486	1.53300	1.20767	1.36621
1.30	1.74521	1.56292	1.60280	1.26265	1.42842
1.35	1.83050	1.63931	1.68114	1.32436	1.49823
1.40	1.92582	1.72467	1.76867	1.39332	1.57624
1.45	2.03191	1.81968	1.86611	1.47008	1.66308
1.50	2.14957	1.92505	1.97417	1.55520	1.75938
1.55	2.27959	2.04150	2.09359	1.64928	1.86580
1.60	2.42283	2.16977	2.22514	1.75291	1.98304
1.65	2.58015	2.31066	2.36962	1.86673	2.11180
1.70	2.75244	2.46495	2.52785	1.99138	2.25282
1.75	2.94062	2.63348	2.70067	2.12753	2.40684
1.80	3.14564	2.81708	2.88896	2.27586	2.57464
1.85	3.36847	3.01664	3.09362	2.43708	2.75703
1.90	3.61013	3.23306	3.31555	2.61192	2.95482
1.95	3.87163	3.46725	3.55572	2.80111	3.16885
2.00	4.15405	3.72016	3.81509	3.00544	3.40000

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