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16. Abstract

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The comparative analyses found that both models reasonably replicated observed counts and neither model emerged as clearly superior. Several enhancements were recommended for the Texas Model. These included implementation of an equilibrium option and implementation of an option for multiple user-specific impedance adjustment relationships.

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A COMPARATIVE ANALYSIS OF TWO CAPACITY RESTRAINT ASSIGNMENT MODELS USED IN TEXAS

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Research Report 1153-5

Study 2-10-89-1153
Improving the Efficiency, Effectiveness and Responsiveness of the Traffic Assignment Process

Sponsored by

Texas Department of Transportation

in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
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METRIC (SI*) CONVERSION FACTORS

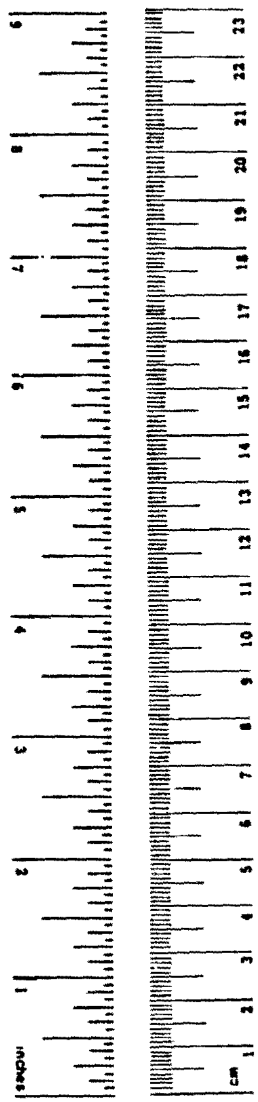
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

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

TEMPERATURE (exact)

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



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
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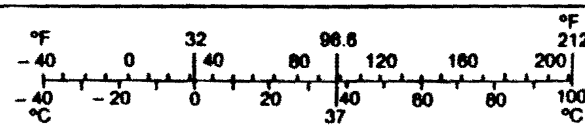

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

As part of the investigation to improve the assignment models, a comparative analysis of the Texas Capacity Restraint Procedure and the Joint Model Capacity Restraint Procedure was undertaken. The basic goal of these analyses was to attempt to objectively compare the two procedures, evaluate how the results of the two procedures differ, and identify (if possible) the primary sources of any differences that may be observed in their ability to replicate observed improvements to one or both procedures.

The comparative analyses found that both models reasonably replicated observed counts and neither model emerged as clearly superior. Several enhancements were recommended for the Texas Model. These included implementation of an equilibrium option and implementation of an option for multiple user-specific impedance adjustment relationships.

DISCLAIMER

EXECUTIVE SUMMARY

The two capacity restraint assignment models currently being used in Texas, the Texas Capacity Restraint Procedure (Texas Model) and the Dallas-Fort Worth Joint Model Capacity Restraint Procedure (Joint Model), represent two different approaches for developing capacity restraint assignments. As a part of the investigation to improve the assignment results, a detailed comparative analysis of these two models was undertaken. The analysis focuses on the abilities of the two models to replicate observed counts. It was anticipated that this analysis would provide the basis for recommending improvements to one or both models.

Two Dallas-Fort Worth networks and trip tables were selected as the data base for analyzing the Texas Model and the Joint Model: the 1986 base year regional assignment network and the 1986 East Dallas County subarea assignment network. The Houston-Galveston regional network could not be used in the comparison due to software limitations in the Joint Model (i.e., the 2,643 zones and external stations used in the Houston-Galveston region substantially exceed the 800-zone limit of the Joint Model). The North Central Texas Council of Governments performed the assignments and provided the results using the Joint Model. Two applications of the Texas Model were performed for each network (i.e., one using Dallas-Fort Worth speed/capacity network parameters and one borrowing speed/capacity parameters developed for the Houston-Galveston region for use with the Texas Model).

The following highlights the report's key findings and recommendations:

- **Ability to replicate counts:** Neither model was superior in matching observed counts. In view of the major structural differences, both models provide comparable results relative to counts.

- **Minimum time versus minimum cost paths:** Neither the minimum time paths (employed in the Texas Model) nor the minimum cost paths (employed in the Joint Model) emerged as the preferred approach. The minimum cost path approach offers some salient advantages for dealing with toll facilities. Therefore, it is recommended that a minimum cost path option be implemented in the Texas Package.

- **Importance of initial speeds and capacities:** The analysis suggests that the initial network speed estimates have more impact on the assignment results than the precision of the capacity estimates. It is recommended that both models would benefit from more refinement of the initial speed estimates during the model calibration process.

- **Equilibrium recommendation:** It is recommended that an equilibrium option be implemented in the Texas Model (which will relieve the analyst from pre-specifying iteration weights). Both the U.S. Department of Transportation and the Environmental Protection Agency encourage the use of equilibrium assignment techniques. Such equilibrium techniques cannot be implemented in an incremental model like the Joint Model.

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I. INTRODUCTION

As part of the investigation to improve the assignment models, a comparative analysis of the Texas Capacity Restraint Procedure and the Joint Model Capacity Restraint Procedure was undertaken. The focus of these analyses was to identify how the results from these two procedures differ relative to their comparison to counts. If the models were found to significantly differ in their ability to replicate the observed counts, the analyses would attempt to identify the procedural differences in the models which accounted for most of the difference in the assignment results. In other words, the basic goal of these analyses was to attempt to objectively compare the two procedures, evaluate how the results of the two procedures differ, and identify (if possible) the primary sources of any differences that may be observed in their ability to replicate observed volumes. It was anticipated that these comparisons would provide the basis for recommending improvements to one or both procedures.

Chapter I defines the fundamental differences between the Joint Model Capacity Restraint Procedure (Joint Model) and the Texas Capacity Restraint Assignment Model (Texas Model). Chapter II of this report outlines the key procedural differences in the two models (i.e., differences in the theoretical structure). Chapter III presents an analysis of the effective differences in the highway capacity inputs used by the two models. Chapter IV focuses on the differences in the link impedances and impedance adjustments by volume to capacity (V/C) ratio.

SELECTION OF APPLICATIONS FOR COMPARISONS

The Joint Model Capacity Restraint Procedure was used to develop and evaluate the Dallas-Fort Worth regional travel demand models. The assignment model software was developed and implemented as a part of the North Central Texas Council of Governments' (NCTCOG) Multimodal Transportation Analysis Package (MTAP) prior to its adoption as a part of the Joint Model for the region. The MTAP system was developed using a subarea focusing approach.

The Joint Model regional highway assignments are performed using approximately 800 regional analysis zones and external stations. The results from the regional assignments are used to analyze the freeway system.

For arterial analyses, the region has been divided into a series of subareas. The zones within a subarea are much smaller than the regional analysis zones (i.e., the zone structure within a subarea is more detailed). The zone structure representing the portion of the region outside of the subarea is less detailed so that 800 or fewer zones and external stations are employed for a subarea application. The results from a subarea application are used to analyze the arterial streets within the subarea.

Since neither the regional assignments nor the subarea assignments employ more than 800 zones and external stations, the software implementing the Joint Model's Capacity Restraint Procedure was developed with a limit of 800 zones and external stations. In contrast, the Houston-Galveston regional travel demand models employ 2,643 zones and external stations in their highway assignments. The Texas Model is used to perform the highway assignments for the Houston-Galveston region. The 800-zone software limitation of the Joint Model effectively precludes its application to the 2,600-zone Houston-Galveston network for comparison with the Texas Model results. It should be recognized from the outset that the use of Dallas-Fort Worth networks which were developed and refined through applications likely creates some bias in favor of the Joint Model in the results. This should be remembered as the results from the different models are presented.

Since the Joint Model is used to perform both regional assignments and subarea assignments, it was felt that the Texas Model should also be applied at both level of detail for comparison of assignment results. The 1986 base year Regional Assignment network and the 1986 East Dallas County Assignment network were used for the comparison applications. The East Dallas County subarea was recommended for use in these analyses by the NCTCOG.

JOINT MODEL APPLICATIONS

The two assignments using the Joint Model were performed by the NCTCOG. The link data and capacity restraint assignment results for each link were provided to TTI by the NCTCOG. The trip tables used for these assignments were also provided.

TEXAS MODEL APPLICATIONS

As discussed in detail in subsequent chapters, the link capacities and initial link speeds used by the Joint Model are different from those commonly used with the Texas Model. It was decided, therefore, to perform two Texas Model assignments at each of the two levels of detail. The first Texas Model assignment at each level of detail used the same capacities and initial speeds employed in the Joint Model applications.

Because the Houston-Galveston regional models use the Texas Model, the Houston-Galveston capacity/speed look-up table was used to estimate a new set of link capacities and initial link speeds which are more like those commonly used in conjunction with the Texas Model than those used with the Joint Model. Also, in the Texas Model applications in Houston, a freeway access/egress time penalty is employed to avoid overloading the freeways with very short trips. Since ramps are coded in the Dallas-Fort Worth networks (which should in part account for the freeway access/egress delays), the time penalties used in the Texas Model applications with Houston Galveston speeds and capacities were reduced by approximately 50 percent. No freeway access/egress time penalties were used with the Texas Model applications using the Dallas-Fort Worth speeds and capacities. The four assignments performed using the Texas Model were performed by TTI. The results of the assignments and the Joint Model assignments are presented in Chapters V and VI. Chapter VII summarizes the findings and recommendations.

II. OVERVIEW OF BASIC DIFFERENCES IN THE MODELS

The Texas Model developed and implemented in the ASSIGN SELF-BALANCING routine of the Texas Package in the late 1970's is an iterative capacity restraint procedure which uses a variation of the old Bureau of Public Roads (BPR) impedance adjustment function to estimate new link travel time between iterations. Some interesting features of the Texas Model are:

1. The procedure is an iterative capacity restraint assignment procedure.
2. For two-way links, the procedure uses nondirectional speeds (travel times) and applies the capacity restraint using nondirectional volumes and capacities.
3. The V/C ratio (used in computing the impedance adjustment) is computed using a cumulative weighted average of the volumes from all the proceeding iterations (not just the last iteration).
4. The impedance adjustment is always relative to the initial (or input) impedance and does not consider the impedances used on intermediate iterations.
5. The user specifies the desired number of iterations and the desired iteration weighting. For most applications, five or six iterations are customarily used.
6. The input link speeds are assumed to represent the average speeds on the links for link volumes representing a V/C ratio of approximately 0.85. Impedances are generally reduced for V/C ratios of less than 0.85 and are generally increased for V/C ratios of greater than 0.85.

In adopting the Joint Model for the Dallas-Fort Worth region, the NCTCOG's Capacity Restraint Assignment Procedure (1) was adopted. The Joint Model procedure for 24-Hour assignments differs from the Texas Model in many key aspects. These include:

1. The Joint Model procedure is an incremental rather than an iterative procedure.
2. The impedance used in finding the minimum impedance path is estimated link travel costs (i.e., a generalized cost estimate based on the link distance, the link travel time, and the link toll) rather than simple estimated link travel time (as normally used in the Texas Procedure). In other words, the Joint

Model assigns trips based on minimum cost paths rather than minimum time paths.

3. The Joint Model builds "bushes" rather than "trees."
4. The Joint Model uses directional speeds, directional capacities and directional V/C ratios while the Texas Model uses nondirectional speeds, capacities and V/C ratios for the two way links.
5. The link capacities input to the Joint Model are essentially directional hourly capacities while the link capacities input to the Texas Model are nondirectional 24-hour capacities. In performing 24-hour assignments using the Joint Model, the V/C ratio is computed by factoring the 24-hour directional volume to represent an estimated peak-hour directional volume and dividing the estimated peak-hour directional volume by the link's directional hourly capacity. Only two user-supplied factors can be employed per application (i.e., a factor for high capacity facilities and a factor for low capacity facilities). For the Dallas-Fort Worth regional assignment applications, the 24-hour directional assignment volumes are factored by either 0.10 for high capacity facilities (e.g., freeways) or 0.12 for low capacity facilities (e.g., normal surface streets). Different factor pairs are used for some subarea applications in the Dallas Fort-Worth study area. The estimated peak-hour V/C ratio for a link is used to estimate the link's delay for updating the link's speed. This approach, in effect, defines 24-hour capacities that are different from those used in the Houston-Galveston highway networks. Chapter III provides a more detailed comparison of the two capacity approaches.
6. The Joint Model procedure essentially splits the trip table up into three trip tables. The two parameters used in splitting the trip table are:
    - The maximum number of iterations (currently set at 3), and,
    - The number of trips to be loaded in a given iteration (currently set at 10,000).

   Splitting the input trip table row into the three trip tables is essentially performed as follows:

- If the zone's trip origins (i.e., the sum of the row of the trip table) is less than or equal to 10,000, then all the zone's trip origins are assigned in the first iteration trip table;
- If the zone's trip origins (i.e., the sum of the row of the trip table) is greater than 10,000 and less than or equal to 20,000, then essentially half of each of the zone's interchange volumes (rounded to integer interchange volumes) are assigned in the first iteration trip table and the remainder in the second iteration trip table;
- If the zone's trip origins (i.e., the sum of the row of the trip table) is greater than 20,000, then essentially one-third of each of the zone's interchange volumes (rounded to integer interchange volumes) are assigned in each of the three iteration trip tables.

The effect of this technique "is to load smaller increments of larger trip interchanges in an attempt to avoid the impacts of loading a large number of trips with an all-or-nothing path. . . .The technique allows all zones an opportunity to assign some trips before critical links are overloaded" (reference 1, pages 121-123).

7. Depending on the parameter settings, the network speeds and impedances may be updated several hundred times during the Joint Model assignment process. In the Texas Model, the impedances (speeds) are updated between iterations.

   The Joint Model procedure has three parameters which control link updating. The first two are the lower and upper bounds of the total number of trips that will be loaded before updating the link impedance. These are currently defined at 20,000 and 100,000 trips. The third parameter is the critical V/C ratio which defines congestion (currently set at 0.8). As more and more links reach congestion, the number of trips to be loaded between speed updates is reduced.

8. The Joint Model method used to estimate the effect of a given V/C ratio on a link's travel time (i.e., speed) is noticeably different from the Texas Model both in formulation and impact. The Joint Model uses different functions for

freeway and non-freeway links to estimate the delay minutes per mile based on the link's V/C ratio; the Texas Model uses a single formula (essentially a variation of the traditional BPR formula) to estimate the percentage change in link travel time based on the link's V/C ratio. Table 1 provides some example capacity restrained speeds from the two procedures for two typical links (i.e., a freeway link with a 60 mph input speed and an arterial link with a 30 mph input speed).

As may be observed, the freeway speeds decay much more rapidly in the Joint Model than in the Texas Model. The arterial speeds also decay more rapidly in the Joint Model but not nearly as dramatically as the freeways. In the joint Model, the maximum delay per mile on a freeway link is 60 minutes; while the maximum delay per mile on an arterial is 10 minutes. Differences in the capacity restraint adjustments are discussed in more detail in Chapter IV.

Table 1
Example Capacity Restrained Speeds by V/C Ratio

	Freeway Link (Input Speed = 60 mph)		**Arterial Link** (Input speed = 30 mph)	
V/C Ratio	Joint Model Speed	Texas Model Speed	Joint Model Speed	Texas Model Speed
0.0	59.1	65.2	29.3	32.6
50.0	49.5	64.6	27.0	32.3
70.0	37.2	62.8	24.9	31.4
85.0	25.5	60.0	22.7	30.0
100.0	15.0	56.1	20.0	28.0
110.0	9.8	52.6	17.9	26.3
120.0	6.2	48.7	15.7	24.4
130.0	3.8	44.5	13.4	22.2
150.0	1.4	35.7	9.2	17.9

9. The initial (or input) link speeds also differ in the two modeling procedures. The Joint Model speeds might be termed zero volume speeds while the Texas

Model speed input speeds are 24-hour speeds. The differences in the input speeds are discussed in more detail in Chapter IV.

Clearly, the two procedures are different. Indeed, it would be easier to list the similarities between the two procedures rather than their differences. Their similarities include:

1. Both load an all-or-nothing path between zone pairs (as contrasted with a stochastic assignment procedure).
2. A networks' A-nodes, B-nodes and link distances could be the same for the two procedures.
3. Both input and assign a 24-hour origin-destination (O-D) trip table.

Even though the two models are different structurally, they have both been used successfully in operational studies.

III. DIFFERENCES IN THE LINK CAPACITY ESTIMATES

The purpose of this chapter is to more closely examine the effective differences in the capacities used with the two procedures. Because the size of the Houston-Galveston region is comparable to the Dallas-Fort Worth region and uses the Texas 24-hour capacity restraint assignment procedure, the Houston-Galveston capacity estimates were selected for comparison with the Dallas-Fort Worth Joint Model.

CAPACITY LOOK-UP TABLES

Both the Dallas-Fort Worth region and the Houston-Galveston region employ capacity look-up tables in developing highway networks. Both use facility type and area type as stratification variables in their look-up tables. The five area type stratifications used by the two regions are summarized in Table 2. The area type stratifications used by the two regions appear to be similar.

The facility types used for the capacity look-up tables for the two regions are summarized in Table 3. These facility type stratifications reflect a fundamental difference in the methods used by the two regions to represent freeways in their travel model networks. In the Dallas-Fort Worth region, the freeways are detailed coded (i.e., the freeway's main lanes are represented by two one-way links and the ramps and frontage roads are individually coded using one-way links). The Dallas-Fort Worth region is unique in Texas in its exclusive use of detailed coding for freeway facilities. In the Houston-Galveston region (like other urban areas in Texas), the freeways are generally represented by a single two-way link. Links representing sections of freeways with frontage roads coded with a higher 24-hour nondirectional capacity to represent both the freeway capacity and the capacity added by the provision of frontage roads. In Houston, freeways and tollways are also stratified as either radial or circumferential to allow for different directional split assumptions in the nondirectional capacity computations. Houston also uses functional types for one-way arterial links and one-way arterial pair links (i.e., a two-way link representing a one-way pair of parallel streets) to reflect the reduced impact of left turns in one-way operations.

Table 2
Area Type Stratifications for Capacity Look-up Tables

Dallas-Fort Worth Area Types	Houston-Galveston Area Types
CBD Fringe Urban Residential Suburban Residential Rural	CBD Urban Inner Suburban Suburban Rural

Table 3
Facility Type Stratifications for Capacity Look-up Tables

Dallas-Fort Worth Facility Types	Houston-Galveston Facility Types
Freeway Principal Arterial - Divided or One-way Principal Arterial - Undivided Minor Arterial - Divided or One-way Minor Arterial - Undivided Collector - Divided or One-way Collector - Undivided Local - Divided or One-way Local - Undivided Ramp Frontage Road - Divided or One-way Frontage Road - Undivided	Radial Freeway - Without Frontage Roads Radial Freeway - With Frontage Roads Circumferential Frwy - Without Frontage Roads Circumferential Frwy - With Frontage Roads Principal Arterials with Grade Separations Principal Arterials - Divided Principal Arterials - Undivided Other Arterials - Divided Other Arterials - Undivided One-way Arterial Pairs One-way Arterial Links Saturated Arterials Major Collectors Collectors Ferries Radial Tollway - Without Frontage Roads Radial Tollway - With Frontage Roads Circum. Tollway - Without Frontage Roads Circum. Tollway - With Frontage Roads

DALLAS-FORT WORTH JOINT MODEL CAPACITIES

As previously discussed, the link capacities input to the Joint Model are essentially directional hourly capacities rather than 24-hour nondirectional capacities. In performing 24-hour assignments using the Joint Model, the V/C ratio is computed by factoring the 24-hour directional volume to represent an estimated peak-hour directional volume and dividing the estimated peak-hour directional volume by the link's directional hourly capacity. Only two user supplied factors can be employed for an application (i.e., a factor for high capacity facilities and a factor for low capacity facilities). For the Dallas-Fort Worth regional assignment applications, the 24-hour directional assignment volumes are factored by either 0.10 for high capacity facilities (e.g., freeways) or 0.12 for low capacity facilities (e.g., normal surface streets). Different factor pairs are used for some subarea applications in the Dallas Fort-Worth study area. The estimated directional peak-hour V/C ratio is used to estimate the directional link delay for adjusting the link's directional travel time.

The Dallas-Fort Worth capacity look-up table is presented in Table 4. As may be observed, the capacities are specified in terms of the average vehicle capacity per hour per lane. To compute the directional peak-hour capacity on a link, the appropriate capacity look-up table value is multiplied by the number of lanes in that direction.

It is interesting to note that the frontage road capacities are the same as the minor arterial capacities. Likewise, the capacities for collectors and local streets are the same.

DALLAS-FORT WORTH 24-HOUR CAPACITY COMPUTATIONS

In the Dallas Fort-Worth Joint Model, the 24-hour directional volumes are converted to peak-hour volumes by applying a peak-hour conversion factor. Factors of 0.10 and 0.12 are generally used for high-capacity and low-capacity facilities respectively (slightly different factors are used for some subarea assignments). This process can essentially be reversed, and the peak-hour conversion factors can be used to convert the hourly directional capacities to 24-hour directional capacities. The two-way (or nondirectional) capacities can be computed by simply adding the directional capacities.

Table 4
Dallas-Fort Worth Directional Hourly Capacities per Lane

Functional Class	Area Type				
	CBD	Fringe	Urban Residential	Suburban Residential	Rural
Freeway	1,800	1,850	1,875	1,950	2,000
Principal Arterial - Divided or One-way	550	600	650	725	800
Principal Arterial - Undivided	500	550	600	675	725
Minor Arterial - Divided or One-way	550	600	625	700	750
Minor Arterial - Undivided	500	550	575	625	675
Collector - Divided or One-way	450	475	500	550	575
Collector - Undivided	400	425	450	500	525
Local - Divided or One-way	450	475	500	550	575
Local - Undivided	400	425	450	500	525
Ramp	1,100	1,200	1,250	1,400	1,500
Frontage Road - Divided or One-way	550	600	625	700	750
Frontage Road - Undivided	500	550	575	625	675

HOUSTON-GALVESTON 24-HOUR CAPACITY COMPUTATIONS

The procedure used to convert peak-hour directional capacities to 24-hour nondirectional capacities accounts for a major portion of the differences between the Houston-Galveston 24-hour capacities and the Dallas-Fort Worth 24-hour capacities. It is important, therefore, to closely examine the computational procedure used to estimate the 24-hour nondirectional capacities for the Houston-Galveston region. Two sets of capacities were developed for the Houston-Galveston region: (1) a set of directional one-hour capacities, and (2) a set of nondirectional 24-hour capacities. The 24-hour nondirectional capacities are used to perform 24-hour capacity restraint assignments. The hourly directional capacities are used when performing directional peak-hour assignments. The conversion of directional peak capacities to 24-hour nondirectional capacities requires the use of two parameters which vary by area type and facility type. These two parameters are: the expected directional split in the peak-hour and the percent of the nondirectional 24-hour volume that is expected to occur in the peak-hour. The procedure may be described computationally as follows:

$$PC_{npd}=\frac{1-D}{D}PC_{pd}$$

$$C_{nd}=\frac{PC_{pd}+PC_{npd}}{K2}$$

Where:

C_{nd}	=	24-hour nondirectional capacity on a two-way link.
PC_{pd}	=	hourly capacity in the peak direction.
D	=	directional split (the portion of the nondirectional peak-hour volume expected to occur in the peak direction).
PC_{npd}	=	expected peak-hour volume in the non-peak direction.
$K2$	=	nondirectional Peak-Hour Factor (the portion of the 24-hour nondirectional volume expected to occur in the peak-hour, i.e., the nondirectional peak-hour volume divided by the nondirectional 24-hour volume).

The procedure for estimating a 24-hour nondirectional capacity is just the reverse of the procedure used to estimate the peak-hour directional volumes from a 24 hour nondirectional volume estimate.

Table 5 summarizes the expected peak-hour directional splits reflected in the Houston-Galveston 24-hour capacities. Table 6 summarizes the peak-hour factors used in estimating the Houston-Galveston 24-hour capacities.

Table 5
Houston-Galveston Directional Split Assumptions*

	Area Types				
Facility Type	CBD	Urban	Inner Suburban	Suburban	Rural
Radial Freeway (without frontage roads)	.550	.550	.575	.600	.650
Radial Freeway (with frontage roads)	.550	.550	.575	.600	.650
Circum. Freeway (without frontage roads)	.550	.550	.550	.550	.550
Circum. Freeway (with frontage roads)	.550	.550	.550	.550	.550
Principal Arterial with Grade Separations	.540	.530	.540	.560	.580
Principal Arterial - Divided	.540	.530	.540	.560	.580
Principal Arterial - Undivided	.540	.530	.540	.560	.580
Other Arterial - Divided	.540	.530	.540	.570	.600
Other Arterial - Undivided	.540	.530	.540	.570	.600
One-way Arterial Pairs	.540	.530	.540	.560	.580
One-way Arterial Links	.540	.530	.540	.560	.580
Saturated Arterials	.510	.510	.520	.530	.565
Major Collectors	.540	.530	.540	.570	.625
Collectors	.560	.570	.580	.675	.750
Ferries	.600	.600	.600	.600	.600
Radial Tollway (without frontage roads)	.575	.600	.625	.650	.700
Radial Tollway (with frontage roads)	.575	.600	.625	.650	.700
Circum. Tollway (without frontage roads)	.550	.550	.550	.550	.550
Circum. Tollway (with frontage roads)	.550	.550	.550	.550	.550

* Portion of the nondirectional peak-hour volume in the peak direction.

It must be emphasized that the K2 factors represents the ratio of the nondirectional peak-hour volume to the nondirectional 24-hour volume. Given the peak-hour directional split, the directional peak-hour factors can be estimated from the nondirectional peak-hour factors. This procedure can be described as follows:

$$K1 = 2D(K2)$$

Where:

K1 = directional Peak-Hour Factor - the portion of the 24-hour directional volume expected to occur in the peak-hour (i.e., the directional peak-hour volume divided by the directional 24-hour volume).

Using this procedure, the equivalent directional peak-hour conversion factors (i.e., the K1 factors) were computed and are summarized in Table 7.

Table 6
Houston-Galveston Nondirectional Peak-hour Factors

Facility Type	CBD	Urban	Inner Suburban	Suburban	Rural
	Area Types				
Radial Freeway (without frontage roads)	.0750	.0700	.0750	.0850	.1000
Radial Freeway (with frontage roads)	.0750	.0700	.0750	.0850	.1000
Circum. Freeway (without frontage roads)	.0750	.0700	.0750	.0850	.1000
Circum. Freeway (with frontage roads)	.0750	.0700	.0750	.0850	.1000
Principal Arterial with Grade Separations	.0900	.0813	.0820	.0860	.0960
Principal Arterial - Divided	.0900	.0825	.0840	.0920	.1025
Principal Arterial - Undivided	.0900	.0825	.0840	.0920	.1025
Other Arterial - Divided	.1000	.0825	.0900	.0970	.1100
Other Arterial - Undivided	.1000	.0825	.0900	.0970	.1100
One-way Arterial Pairs	.0900	.0825	.0840	.0920	.1025
One-way Arterial Links	.0900	.0825	.0840	.0920	.1025
Saturated Arterials	.0900	.0800	.0800	.0800	.1000
Major Collectors	.1000	.0825	.0900	.0970	.1200
Collectors	.1150	.0950	.0950	.1100	.1500
Ferries	.1000	.1000	.1000	.1000	.1000
Radial Tollway (without frontage roads)	.0950	.1000	.1050	.1100	.1150
Radial Tollway (with frontage roads)	.0950	.1000	.1050	.1100	.1150
Circum. Tollway (without frontage roads)	.0950	.1000	.1050	.1100	.1100
Circum. Tollway (with frontage roads)	.0950	.1000	.1050	.1100	.1100

COMPARISON OF THE PEAK-HOUR FACTORS

In the Dallas-Fort Worth Joint Model, the 24-hour directional volumes are converted to peak-hour volumes by applying one of two directional peak-hour factors. Directional peak-hour factors of 0.10 and 0.12 are generally used for high-capacity and low-capacity facilities respectively (slightly different factors are used for some subarea assignments). These, of course, are the same factors used to reverse the process and estimate a directional 24-hour capacity from a directional peak-hour capacity. Hence, the 0.10 and 0.12 values are directly comparable to the Houston-Galveston factors presented in Table 7.

Table 7
Houston-Galveston Directional Peak-hour Factors

Facility Type	CBD	Urban	Inner Suburban	Suburban	Rural
	Area Types				
Radial Freeway (without frontage roads)	.0825	.0770	.0863	.1020	.1300
Radial Freeway (with frontage roads)	.0825	.0770	.0863	.1020	.1300
Circum. Freeway (without frontage roads)	.0825	.0770	.0825	.0935	.1100
Circum. Freeway (with frontage roads)	.0825	.0770	.0825	.0935	.1100
Principal Arterial with Grade Separations	.0972	.0862	.0886	.0963	.1114
Principal Arterial - Divided	.0972	.0875	.0907	.1030	.1189
Principal Arterial - Undivided	.0972	.0875	.0907	.1030	.1189
Other Arterial - Divided	.1080	.0875	.0972	.1106	.1320
Other Arterial - Undivided	.1080	.0875	.0972	.1106	.1320
One-way Arterial Pairs	.0972	.0875	.0907	.1030	.1189
One-way Arterial Links	.0972	.0875	.0907	.1030	.1189
Saturated Arterials	.0918	.0816	.0832	.0848	.1130
Major Collectors	.1080	.0875	.0972	.1106	.1500
Collectors	.1288	.1083	.1102	.1485	.2250
Ferries	.1200	.1200	.1200	.1200	.1200
Radial Tollway (without frontage roads)	.1093	.1200	.1313	.1430	.1610
Radial Tollway (with frontage roads)	.1093	.1200	.1313	.1430	.1610
Circum. Tollway (without frontage roads)	.1045	.1100	.1155	.1210	.1210
Circum. Tollway (with frontage roads)	.1045	.1100	.1155	.1210	.1210

The Houston-Galveston directional peak-hour factors for freeways vary from 0.077 in the urban area type to 0.13 for radial freeways in rural areas. The Dallas-Fort Worth Joint Model uses a single factor for all freeways (i.e., 0.10 for regional assignments). Clearly these differences can result in substantially different 24-hour capacity estimates. If the Houston-Galveston region had used 0.10 in converting their directional hourly capacities on freeways to 24-hour directional capacities, the 24-hour capacities in the CBD and urban area types would have been 17 to 23 percent lower. Similarly, the radial freeway capacities in rural areas would have been 30 percent higher.

As may be observed in Table 7, the Houston-Galveston directional peak-hour factors for arterials vary from about 0.08 to 0.13. The Dallas-Fort Worth Joint Model uses a single factor for all "low capacity" facilities such as arterials (i.e., 0.12 for regional assignments). These differences can result in substantially different 24-hour capacity estimates. If the Houston-Galveston region had used 0.12 in converting their directional hourly capacities on arterials to 24-hour directional capacities, the 24-hour capacities for non-rural arterials would have been 8 to 32 percent lower.

Even if both regions used the same hourly directional capacity estimates, the 24-hour capacity estimates would be extremely different. As will be noted in the next section, the hourly capacity estimates are shown to be another source of the differences in the 24-hour capacities employed in the two regions.

COMPARISON OF TYPICAL HOURLY DIRECTIONAL CAPACITIES

Table 8 summarizes the Dallas-Fort Worth Joint Model directional hourly capacities for some typical facilities. Table 9 summarizes the Houston-Galveston directional hourly capacities for comparable facility types.

The freeway capacity estimates for both regions are similar. The arterial estimates are substantially different. For example, the Dallas-Fort Worth estimates show the rural arterials with the highest capacities of all the area types. In contrast, the Houston-Galveston arterial capacities are the lowest in rural areas. The lower rural arterial capacities in the Houston-Galveston region are primarily attributable to two factors:

1. A much higher percentage of truck traffic is assumed on Houston's rural arterials than on non-rural facilities; and,
2. In the Houston-Galveston capacity estimates, the saturation flow rates are adjusted based on the expected relationship between the peak 15-minute flow rate and the peak-hour volume as reflected in the following ratio:

$$\frac{\text{peak-hour volume}}{4 \times (\text{peak 15-minute volume})}$$

Interestingly, the Houston-Galveston assumed signal G/C ratios for rural arterials are higher than for their non-rural counterparts.

The complete set of Houston-Galveston peak-hour directional capacities are provided in Appendix A of this report.

COMPARISON OF TYPICAL 24-HOUR NONDIRECTIONAL CAPACITIES

Table 10 summarizes the Dallas-Fort Worth Joint Model nondirectional 24-hour capacities for some typical facilities. Table 11 summarizes the Houston-Galveston nondirectional 24-hour capacities for comparable facility types.

The 24-hour freeway capacity estimates for the two regions are substantially different. Since the hourly capacity estimates are at least similar, the bulk of the differences in the 24-hour capacities is attributable to differences in the conversion for peak-hour directional capacities to 24-hour nondirectional capacities.

The 24-hour arterial capacity estimates are also substantially different. These differences are attributable to both the differences in the estimated hourly capacities and the differences in the factors used to convert from hour to 24-hour capacities.

COMPARISON OF NETWORK VMT CAPACITIES

The assignment model comparisons used two basic networks from the Dallas-Fort Worth region: (1) the regional network, and (2) the subarea network for East Dallas County. For each network, two 24-hour nondirectional capacity networks were prepared for application of the Texas Model: One using the Dallas-Fort Worth 24-hour nondirectional capacities and the second using 24-hour nondirectional capacities borrowed from the Houston-Galveston regional travel models. To use the Houston-Galveston capacities, the five area types were assumed to be the same. The facility type equivalences assumed for using the Houston-Galveston capacities were:

Dallas-Fort Worth Functional Class	H-G Facility Type Used
Freeway	Radial Freeway (without Frontage Roads)
Principal Arterial - Divided	Principal Arterial Divided
Principal Arterial - Undivided	Principal Arterial Undivided
Minor Arterial - Divided	Other Arterial - Divided
Minor Arterial - Undivided	Other Arterial - Undivided
Collector - Divided	Major Collector
Collector - Undivided	Collector

As with the Dallas-Fort Worth capacities, frontage roads used the same capacity as minor arterials. Likewise, local streets used the same capacities as collectors. Since there was no equivalence for Ramps in the Houston-Galveston capacity tables, the Dallas-Fort Worth ramp capacities were used.

Table 12 summarizes the Dallas-Fort Worth regional network VMT capacities for the two set of input capacities. As may be observed, the use of the Houston-Galveston capacities would only increase the region's total VMT capacity by 1.1 percent. The Houston-Galveston capacities decreased the region's freeway VMT capacities by 7.1 percent while increasing the non-freeway link capacities by 6.3 percent.

As may be seen in Table 12, the Regional network capacity changes by area type are substantial. The use of the Houston-Galveston capacities would result in major capacity increases in the CBD, fringe, and urban residential areas and a major capacity decrease in the rural areas.

Table 13 provides the same summaries for the East Dallas subarea network. Again, the use of the Houston-Galveston capacities would result in major changes in the VMT capacities by area type.

Table 8
Dallas-Fort Worth Hourly Directional Capacities for Some Typical Roadways

		Hourly Directional Capacities by Area Type				
Functional Class	Lanes	CBD	Fringe	Urban Residential	Suburban Residential	Rural
Freeway	2	3,600	3,700	3,750	3,900	4,000
(without frontage roads)	3	5,400	5,550	5,625	5,850	6,000
	4	7,200	7,400	7,500	7,800	8,000
	5	9,000	9,250	9,375	9,750	10,000
Principal Arterial - Divided	2	1,100	1,200	1,300	1,450	1,600
	3	1,650	1,800	1,950	2,175	2,400
	4	2,200	2,400	2,600	2,900	3,200
Principal Arterial - Undivided	1	500	550	600	675	725
	2	1,000	1,100	1,200	1,350	1,450
	3	1,500	1,650	1,800	2,025	2,175
	4	2,000	2,200	2,400	2,700	2,900
Other Arterial - Divided	2	1,100	1,200	1,250	1,400	1,500
	3	1,650	1,800	1,875	2,100	2,250
	4	2,200	2,400	2,500	2,800	3,000
Other Arterial - Undivided	1	500	550	575	625	675
	2	1,000	1,100	1,150	1,250	1,350
	3	1,500	1,650	1,725	1,875	2,025

Table 9
Houston-Galveston Hourly Directional Capacities for Some Typical Roadways

Facility Type	Lanes	CBD	Urban	Inner Suburban	Suburban	Rural
		Hourly Directional Capacities by Area Type				
Radial Freeway (without frontage roads)	2	3,675	3,875	3,875	3,825	3,750
	3	5,500	5,800	5,800	5,725	5,600
	4	7,350	7,725	7,725	7,625	7,475
	5	9,175	9,650	9,650	9,525	9,350
Principal Arterial - Divided	2	1,425	1,425	1,425	1,425	1,350
	3	2,075	2,075	2,075	2,100	1,975
	4	2,775	2,775	2,775	2,775	2,625
Principal Arterial - Undivided	1	675	675	675	675	650
	2	1,275	1,275	1,300	1,325	1,250
	3	1,850	1,850	1,875	1,900	1,800
	4	2,425	2,450	2,475	2,500	2,375
Other Arterial - Divided	2	1,400	1,375	1,350	1,350	1,275
	3	2,025	2,000	1,975	1,975	1,850
	4	2,700	2,675	2,650	2,625	2,475
Other Arterial - Undivided	1	675	650	650	650	625
	2	1,275	1,275	1,250	1,250	1,200
	3	1,850	1,825	1,825	1,800	1,750

Table 10
Dallas-Fort Worth 24-Hour Nondirectional Capacities for Some Typical Roadways

Functional Class	Total Lanes	CBD	Fringe	Urban Residential	Suburban Residential	Rural
		24-Hour Nondirectional Capacities by Area Type				
Freeway (without frontage roads)	4	72,000	74,000	75,000	78,000	80,000
	6	108,000	111,000	112,500	117,000	120,000
	8	144,000	148,000	150,000	156,000	160,000
	10	180,000	185,000	187,500	195,000	200,000
Principal Arterial - Divided	4	18,330	20,000	21,670	24,170	26,670
	6	27,500	30,000	32,500	36,250	40,000
	8	36,670	40,000	43,330	48,330	53,330
Principal Arterial - Undivided	2	8,330	9,170	10,000	11,250	12,080
	4	16,670	18,330	20,000	22,500	24,170
	6	25,000	27,500	30,000	33,750	36,250
	8	33,330	36,670	40,000	45,000	48,330
Other Arterial - Divided	4	18,330	20,000	20,830	23,330	25,000
	6	27,500	30,000	31,250	35,000	37,500
	8	36,670	40,000	41,670	46,670	50,000
Other Arterial - Undivided	2	8,330	9,170	9,580	10,420	11,250
	4	16,670	18,330	19,170	20,830	22,500
	6	25,000	27,500	28,750	31,250	33,750

Table 11

Houston-Galveston 24-Hour Nondirectional Capacities for Some Typical Roadways

Facility Type	Total Lanes	CBD	Urban	Inner Suburban	Suburban	Rural
		24-Hour Nondirectional Capacities by Area Type				
Radial Freeway	4	89,000	100,500	89,500	67,500	49,000
(without frontage roads)	6	133,500	150,500	134,500	101,000	74,000
	8	178,000	201,000	179,000	135,000	98,500
	10	222,500	251,000	224,000	168,500	123,000
Principal Arterial - Divided	4	29,300	32,600	31,500	27,800	22,700
	6	42,800	47,600	46,000	40,500	33,100
	8	57,000	63,500	61,300	54,100	44,100
Principal Arterial - Undivided	2	13,700	15,200	14,900	13,300	10,800
	4	26,300	29,300	28,700	25,600	20,900
	6	38,000	42,400	41,400	37,000	30,200
	8	50,100	55,900	54,600	48,700	39,800
Other Arterial - Divided	4	25,700	31,500	28,000	24,400	19,200
	6	37,600	45,900	40,900	35,600	28,000
	8	50,100	61,200	54,500	47,400	37,400
Other Arterial - Undivided	2	12,300	15,100	13,400	11,700	9,500
	4	23,700	29,000	25,800	22,500	18,300
	6	34,200	41,900	37,300	32,500	26,500

Table 12

Dallas-Fort Worth Regional Network Capacity Comparisons

Link Group*	Area Type	Number of Links	Link Miles	Network Capacity VMT: Dallas-Ft Worth Capacities	Network Capacity VMT: Houston-Galveston Capacities	Percent Difference
Freeway Links	CBD	37	9	534,960	661,270	23.6%
	Fringe	173	63	3,817,660	5,179,154	35.7%
	Urban Residential	652	299	16,349,813	19,528,478	19.4%
	Suburban Residential	703	400	21,275,280	18,391,708	-13.6%
	Rural	402	322	15,026,200	9,223,905	-38.6%
	All Area types	1,967	1,093	57,003,913	52,984,514	-7.1%
Non-Freeway Links	CBD	790	66	939,883	1,377,901	46.6%
	Fringe	1,052	253	4,037,149	6,380,658	58.0%
	Urban Residential	6,024	2,063	32,275,727	44,250,330	37.1%
	Suburban Residential	4,470	2,022	28,837,095	28,779,708	-.2%
	Rural	2,656	2,171	23,115,780	14,033,583	-39.3%
	All Area types	14,992	6,575	89,205,634	94,822,179	6.3%
All Links	CBD	827	75	1,474,843	2,039,171	38.3%
	Fringe	1,225	316	7,854,809	11,559,812	47.2%
	Urban Residential	6,676	2,362	48,625,540	63,778,807	31.2%
	Suburban Residential	5,173	2,422	50,112,375	47,171,415	-5.9%
	Rural	3,058	2,493	38,141,980	23,257,488	-39.0%
	All Area types	16,959	7,668	146,209,547	147,806,693	1.1%

* Excludes centroid connectors.

Table 13
East Dallas Subarea Network Comparisons

Subarea Link Group*	Area Type	Number of Links	Link Miles	Network Capacity VMT: Dallas-Ft Worth Capacities	Network Capacity VMT: Houston-Galveston Capacities	Percent Difference
Freeway Links	Urban Residential	67	32	1,578,754	2,072,373	31.3%
	Suburban Residential	75	38	1,854,459	1,764,885	-4.8%
	Rural	39	34	1,252,012	843,670	-32.6%
	All Area types	181	103	4,685,225	4,680,928	-.1%
Non-Freeway Links	Urban Residential	722	258	4,326,239	5,869,285	35.7%
	Suburban Residential	651	266	3,504,763	3,419,005	-2.4%
	Rural	346	237	2,429,090	1,391,710	-42.7%
	All Area types	1,719	762	10,260,092	10,679,999	4.1%
All Links	Urban Residential	789	290	5,904,993	7,941,657	34.5%
	Suburban Residential	726	304	5,359,222	5,183,890	-3.3%
	Rural	385	271	3,681,102	2,235,380	-39.3%
	All Area types	1,900	865	14,945,317	15,360,927	2.8%

* Excludes centroid connectors and links outside the subarea.

IV. DIFFERENCES IN LINK IMPEDANCES AND CAPACITY RESTRAINT ADJUSTMENTS

In the Dallas-Fort Worth Joint Model, link impedances are defined in terms of cost rather than simply travel time (as used in the Texas Model). In the assignments, therefore, the paths are minimum cost paths rather than minimum time paths. The purpose of this chapter is to more closely examine the differences in the impedances used by the two models and the differences in their adjustment based on a link's V/C ratio.

INPUT LINK SPEEDS

The input link speeds for the Dallas-Fort Worth Joint Model applications are free speeds or uncongested speeds. Such speeds are often referred to as zero volume speeds. A fairly elaborate procedure is used to estimate these speeds in the Joint Model. This procedure can be briefly described as follows:

> Free speed is calculated using the speed limit, area type, functional class, number of intervening controls and the end node traffic control coded for each link. In general, the functional class and area type determine the delay associated with various traffic controls (e.g., signals, stop signs, yield signs). Traffic control delay is added to the travel time derived from the speed limit, and the speed associated with the new travel time is then posted as the link's free speed . . .
>
> . . . The initial impedance for assignment is based on free or uncongested speeds. It is common practice at NCTCOG to increase the speeds on freeways, frontage roads and principal arterials by 10 percent. This is in recognition of tendencies of the average motorist to exceed the maximum allowable speed.(1)

These speed estimates are computed and used directionally. It should also be noted that these speeds are only used as the starting speeds for the assignment modeling in the Dallas-Fort Worth Joint Models. Two additional sets of speeds are estimated and used in the trip distribution modeling process (i.e., estimated loaded peak speeds and estimated loaded off-peak speeds).

In most applications of the Texas Model, a much simpler approach is employed to define the input speeds. For most applications, a simple speed look-up table (stratified by facility type and area type) is employed for estimating the input link speeds. The input speeds are generally 24-hour nondirectional speeds. These speeds are assumed to roughly represent the typical average 24-hour nondirectional speed for the link with a 24-hour nondirectional V/C ratio of 0.85. In all the Texas urban areas (except Dallas-Fort Worth) the 24-hour speeds are used for both the trip distribution modeling and the starting speeds for the capacity restraint modeling.

The 24-hour speeds used in the Houston-Galveston travel models are summarized in Table A-2 of Appendix A. Table B-2 of Appendix B summarizes the Houston-Galveston 24-hour speeds borrowed for application in the Dallas-Fort Worth networks which used the Houston-Galveston capacities.

Table 14
Average Input Link Speeds for the Dallas-Fort Worth Regional Network

		Area Types				
		CBD	Fringe	Urban Residential	Suburban Residential	Rural
Freeways						
	# Links	37	173	652	703	402
	D-FW Speeds	56.3	57.7	60.5	60.6	61.0
	H-G Speeds	40.0	45.0	50.0	55.0	60.0
Principal Arterials						
	# Links	186	212	869	403	120
	D-FW Speeds	16.9	28.9	33.5	42.2	54.4
	H-G Speeds	17.0	30.0	34.0	38.6	50.3
Minor Arterials						
	# Links	310	305	1,614	1,108	414
	D-FW Speeds	14.8	21.0	28.2	32.4	42.8
	H-G Speeds	17.0	29.5	33.7	36.5	48.1
Collectors						
	# Links	191	226	2,316	1,742	1,489
	D-FW Speeds	14.8	21.5	23.7	27.3	33.1
	H-G Speeds	16.1	24.8	25.8	27.0	36.3
Locals						
	# Links	0	0	0	0	0
Ramps						
	# Links	63	200	724	745	385
	D-FW Speeds	38.8	38.0	36.6	37.5	38.5
	H-G Speeds	17.0	30.0	34.0	37.0	49.0
Frontage Roads						
	# Links	40	109	501	472	248
	D-FW Speeds	19.9	33.0	36.0	37.8	38.7
	H-G Speeds	17.0	30.0	34.0	36.9	48.7

The average Dallas-Fort Worth input link speeds by area type and functional class for the Dallas-Fort Worth regional network are summarized in Table 14. The average Houston-Galveston input speeds (used in conjunction with the Houston-Galveston capacities) for the Dallas-Fort Worth regional network are also summarized in Table 14. As may be noted, the greatest differences occur with the freeway links for the first three area types. These differences are probably largely attributable to the basic definitional differences between uncongested speeds and 24-hour speeds. Without attempting to prejudge which is better, it is probably fair to say that there are some significant differences in the input speeds using the two-speed logic.

Table 15
Average Input Link Speeds for the East Dallas Subarea Network

		Area Types				
		CBD	Fringe	Urban Residential	Suburban Residential	Rural
Freeways						
	# Links	0	0	67	75	39
	D-FW Speeds			61.0	61.0	61.0
	H-G Speeds			50.0	55.0	60.0
Principal Arterials						
	# Links	0	0	89	40	10
	D-FW Speeds			36.1	39.3	52.5
	H-G Speeds			34.0	39.0	50.0
Minor Arterials						
	# Links	0	0	276	181	52
	D-FW Speeds			30.8	31.5	36.3
	H-G Speeds			33.8	36.6	48.1
Collectors						
	# Links	0	0	237	309	216
	D-FW Speeds			24.1	28.3	33.7
	H-G Speeds			25.3	26.4	36.4
Locals						
	# Links	0	0	2	0	0
	D-FW Speeds			23.5		
	H-G Speeds			25.0		
Ramps						
	# Links	0	0	71	82	36
	D-FW Speeds			39.1	38.4	36.4
	H-G Speeds			34.0	37.0	49.0
Frontage Roads						
	# Links	0	0	47	39	32
	D-FW Speeds			39.2	40.3	40.9
	H-G Speeds			34.0	36.9	48.4

Table 15 presents the same summary for the two set of speeds used for the East Dallas subarea network. It should be noted that the links summarized in Table 15 are only the links within the subarea and not the entire subarea network (i.e., the subset of the subarea network links within the East Dallas subarea being studied).

JOINT MODEL TRAVEL TIME ADJUSTMENTS

In the Dallas-Fort Worth Joint Model, the V/C ratio on a link is used to estimate the volume delay on the link. The volume delay is added to the uncongested link travel time. It should be recalled that:

> The initial impedance for assignment is based on free or uncongested speeds. It is common practice at NCTCOG to increase the speeds on freeways, frontage roads and principal arterials by 10 percent. This is in recognition of tendencies of the average motorist to exceed the maximum allowable speed.(1)

This adjusted travel time, of course, can be used to compute the adjusted average speed for the link. The following briefly describes the volume-delay equations employed in the Dallas-Fort Worth Joint Model.

The Joint Model uses two volume-delay equations for daily (i.e., 24-hour) assignments: one for high-capacity facilities and the other for low-capacity facilities. The distinction is made based on the capacity of the link. High-capacity facilities (usually freeways) are defined as those exceeding 3,400 vehicles per hour (one way). A second pair of equations are employed for peak-hour assignments.

The following is the general form of the Dallas-Fort Worth Joint Model's volume-delay equation:

$$\textbf{Delay} = \textbf{Min}\ [\ (\ A\ e^{B(V/C)})\ ,\ M\ ]$$

Where:

Delay	=	minutes of delay per mile. This value is multiplied by the link's distance and the results added to the link's zero volume travel time.
V	=	the peak-hour directional volume assigned to the link. For 24-hour assignments, the daily directional volume is converted to hourly units using a peak-hour factor. Factors of 0.10 and 0.12 are generally used for high-capacity and low-capacity facilities respectively.

C	=	the hourly directional capacity.
A & B	=	coefficients.
M	=	maximum minutes of delay per mile.

The A, B, and M parameters vary by capacity type and type of assignment (i.e., daily versus peak-hour). Table 16 lists the Dallas-Fort Worth Joint Model's calibrated parameters for both daily and peak-hour assignments.

Table 16
Dallas-Fort Worth Joint Model Volume Delay Equation Parameters

Daily Assignments		Peak-hour Assignments	
High-capacity Facilities	Low-capacity Facilities	High-capacity Facilities	Low-capacity Facilities
A = 0.015 B = 5.3 M = 60	A = 0.050 B = 3.0 M = 10	A = 0.015 B = 7.0 M = 60	A = 0.050 B = 4.50 M = 10

As previously discussed, the Joint Model's capacity restraint procedure is an incremental loading procedure. The link travel times are updated periodically during this process to reflect the delays which would result from the traffic accumulated on the links to that point in the incremental loading process. These adjusted travel times are used to compute the link's impedance in cost rather than time. The Dallas-Fort Worth impedance computation is discussed in a later section of this chapter.

TEXAS MODEL TRAVEL TIME ADJUSTMENTS

As previously discussed, the Texas Model capacity restraint procedure is an iterative process. In the Dallas-Fort Worth applications under this study (as in the Houston applications), the capacity restraint model is applied using six iterations. Between iterations, the link impedances are adjusted based on the link's V/C ratio. The V/C ratio is calculated using a weighted average of the assigned volumes from the preceding iterations. The final capacity restraint assignment results are developed, of course, by computing the weighted average of the preceding six assignment volumes. The iteration weights are input by the user. The iteration weights currently being used in the Houston applications for the six iterations are: 10, 10, 20, 20, 20, 20 percent.

The impedance adjustment function used in the Texas Model is based on the FHWA impedance adjustment function (often refer to as the BPR function). The FHWA function assumes the impedance is based on a zero volume link speed. Because the Texas highway networks have traditionally been coded using a 24-hour speed rather than a zero volume speed, a modified version of the FHWA impedance adjustment function was implemented. The formula for the Texas impedance adjustment function is:

$$I_{n+1} = [0.92 + 0.15 \, (V/C)^4] \, I_0$$

Where:

I_0	=	the initial link impedance (travel time) using the 24-hour input speed.
I_{n+1}	=	the link impedance (travel time) for iteration n+1.
V	=	the weighted average 24-hour link volume from iterations 1 to n.
C	=	the 24-hour link capacity.

A constraint is imposed to limit the magnitude of the impedance (travel time) adjustment. The maximum impedance adjustment varies by iteration. Following the initial assignment, the maximum impedance adjustment factor is 2 (i.e., essentially reducing the 24-hour speed by one half). The maximum impedance adjustment factor is increased by 1 for each of the succeeding iteration. To reflect this constraint, the equation could be expressed as:

$$I_{n+1} = \min\{ \, [0.92 + 0.15 \, (V/C)^4] \, I_0 \; , \; [n+1] \, I_0 \, \}$$

This formulation of the equation directly reflects the constraint.

COMPARISON OF TYPICAL SPEEDS BY V/C RATIO

The adjusted travel time on a link, of course, can be readily converted to a link speed. Comparison of the implied changes in link speeds by V/C ratio provides a good way of comparing the two travel time adjustments. For these comparisons, we will assume a typical freeway link with an input speed of 60 mph and a typical arterial link with an input speed of 30 mph. Recalling that in the Joint Model's impedance calculations, the uncongested speeds on freeways, frontage roads, and principal arterials are increased by 10 percent. For this example, the arterial is assumed to be a principal arterial and, hence, the zero volume speed for the freeway is effectively 66 mph and the principal arterial 33 mph. Figure 1 displays the Joint Model's capacity restrained daily speeds for estimated peak- hour link V/C ratios of zero to 1.5. As may be noted, the freeway and arterials tend to converge to a common speed at a V/C ratio between 0.85 and 0.90. At V/C ratios greater than 0.9, arterials would be expected to operate at higher speeds than freeways.

Figure 2 displays the Texas Model's capacity restrained 24-hour speeds for 24-hour nondirectional V/C ratios of zero to 1.5. As may be observed, the Texas Model impedance adjustment function essentially assumes that the input speed represents the average 24-hour nondirectional speed for a link with a 24-hour nondirectional V/C ratio of 0.85. Hence, when the V/C ratio is less than 0.85, the procedure uses a speed that is faster than the input speed.

Comparing the typical speeds in Figures 1 and 2, it is certainly fair to say that they are radically different. The differences are more pronounced for freeways than arterials. These differences are at least in part necessary due to differences in incremental verses iterative capacity restraint techniques.

JOINT MODEL COST IMPEDANCE COMPUTATIONS

As previously noted, the Joint Model uses minimum cost paths rather than minimum times paths. The link impedance (i.e., cost) is calculated based on the capacity restrained link travel time, the link distance and other link costs (i.e., tolls, if any):

$$\textbf{Impedance} = \textbf{a(Time)} + \textbf{b(Dist)} + \textbf{c(Tolls)}$$

Where:

Time	=	the capacity restrained link travel time (in hours).
Dist	=	the link's distance (in miles).
Tolls	=	the toll costs (if any).
a	=	value of time ($/hour).

b = fuel cost ($/mile).

c = consumer price index for converting toll costs to 1984 constant dollars.

The values of the a, b, and c coefficients vary by year as shown in Table 17.

Table 17
Joint Model Highway Impedance Coefficients

Year	Value of Time ($/hour) a	Fuel Cost ($/mile) b	CPI ($/$) c
1980	6.00	0.10	1.30
1984	6.00	0.07	1.00
1986	6.00	0.04	0.95
2000	6.00	0.05	0.70
2010	6.00	0.06	0.50

Figure 3 displays the average cost (impedance) per mile by V/C ratio for a typical freeway link with an input speed of 60 mph and a typical arterial link with an input speed of 30 mph. Again the costs per mile for freeways and arterials intersect at a V/C ratio of about 0.9. Beyond a V/C ratio of 1.0, the freeway costs per mile are generally considerably higher than arterials. Indeed, above 1.2, the freeway costs exceed $1.00 per mile. With these costs, it is difficult to imagine getting freeway assigned volumes in excess of about 1.2 or 1.3.

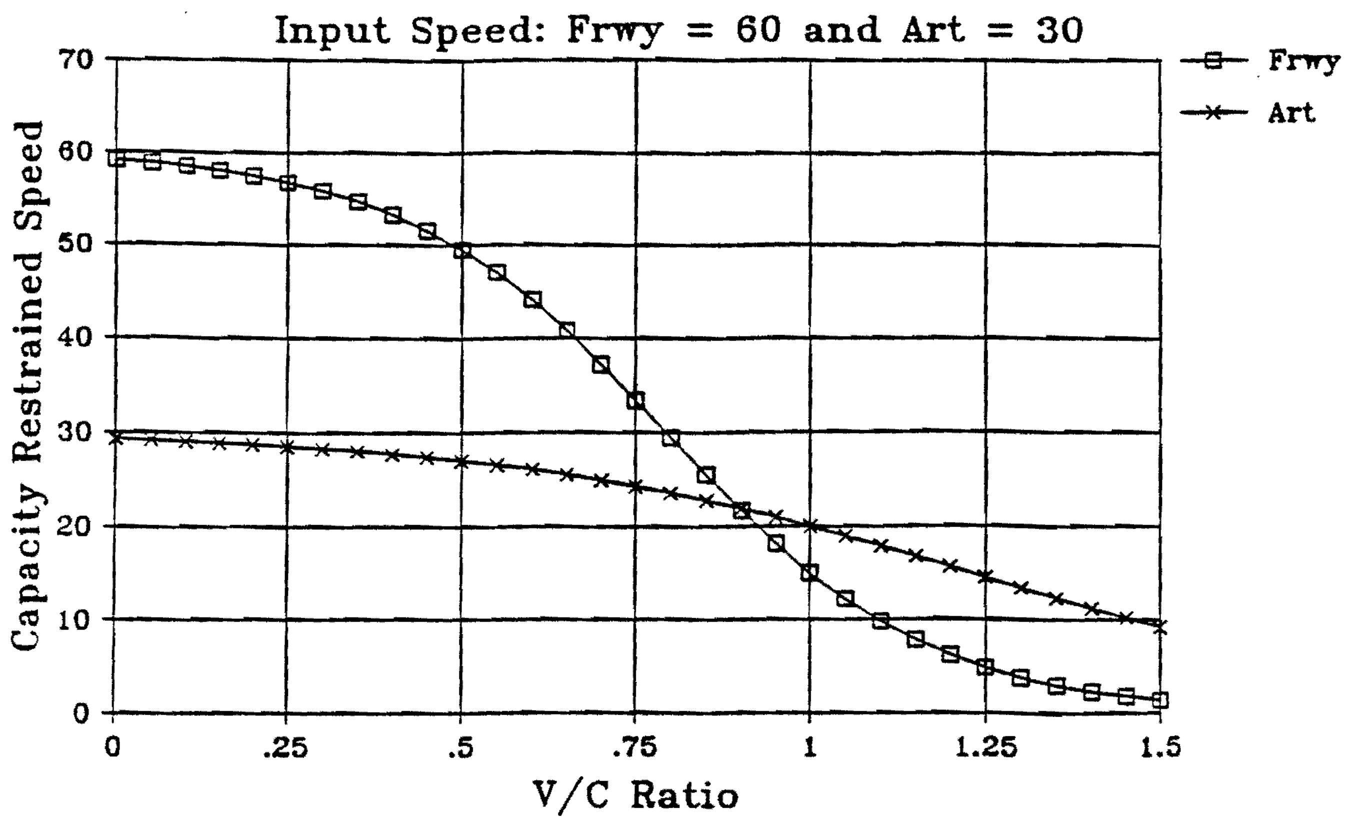

FIGURE 1. Dallas-Fort Worth Joint Model

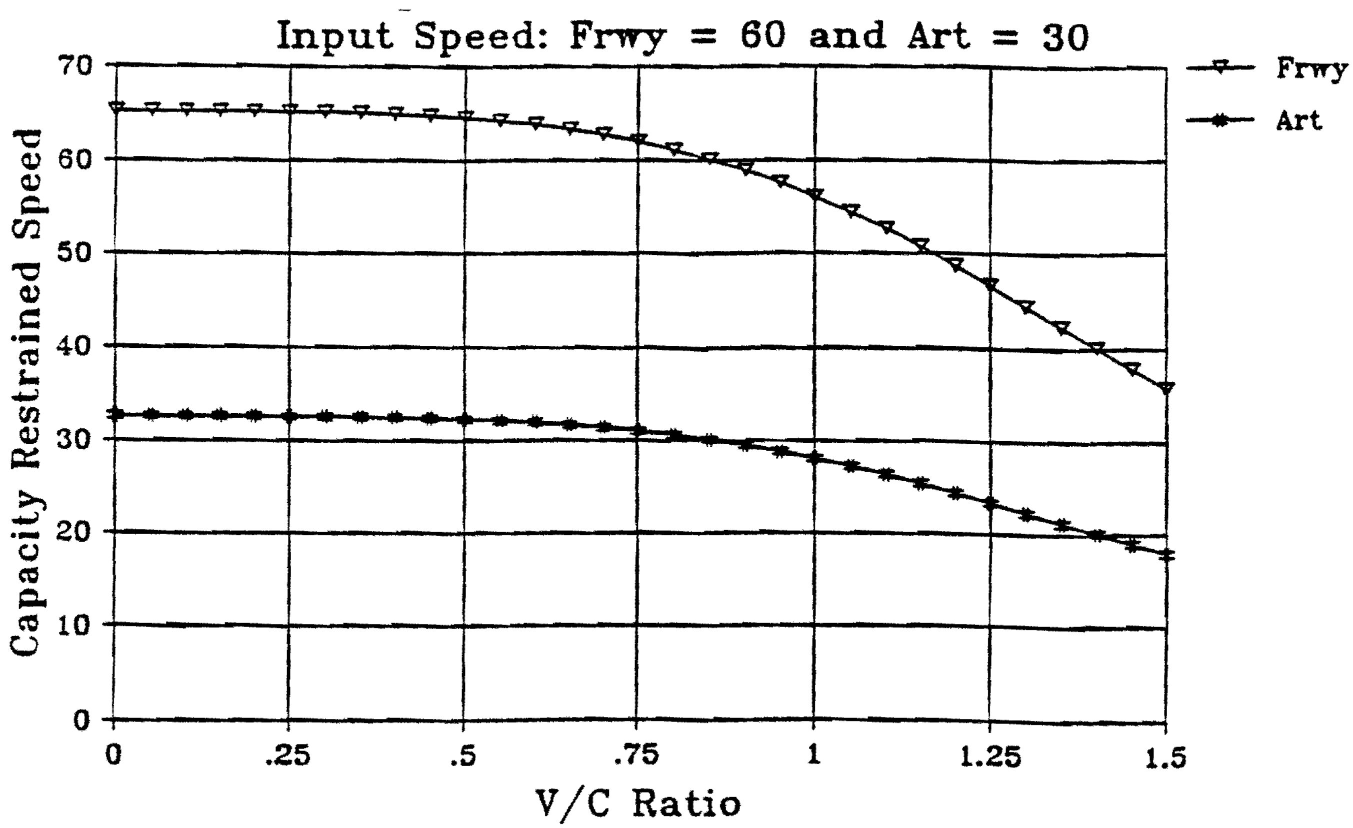

FIGURE 2. Texas Model

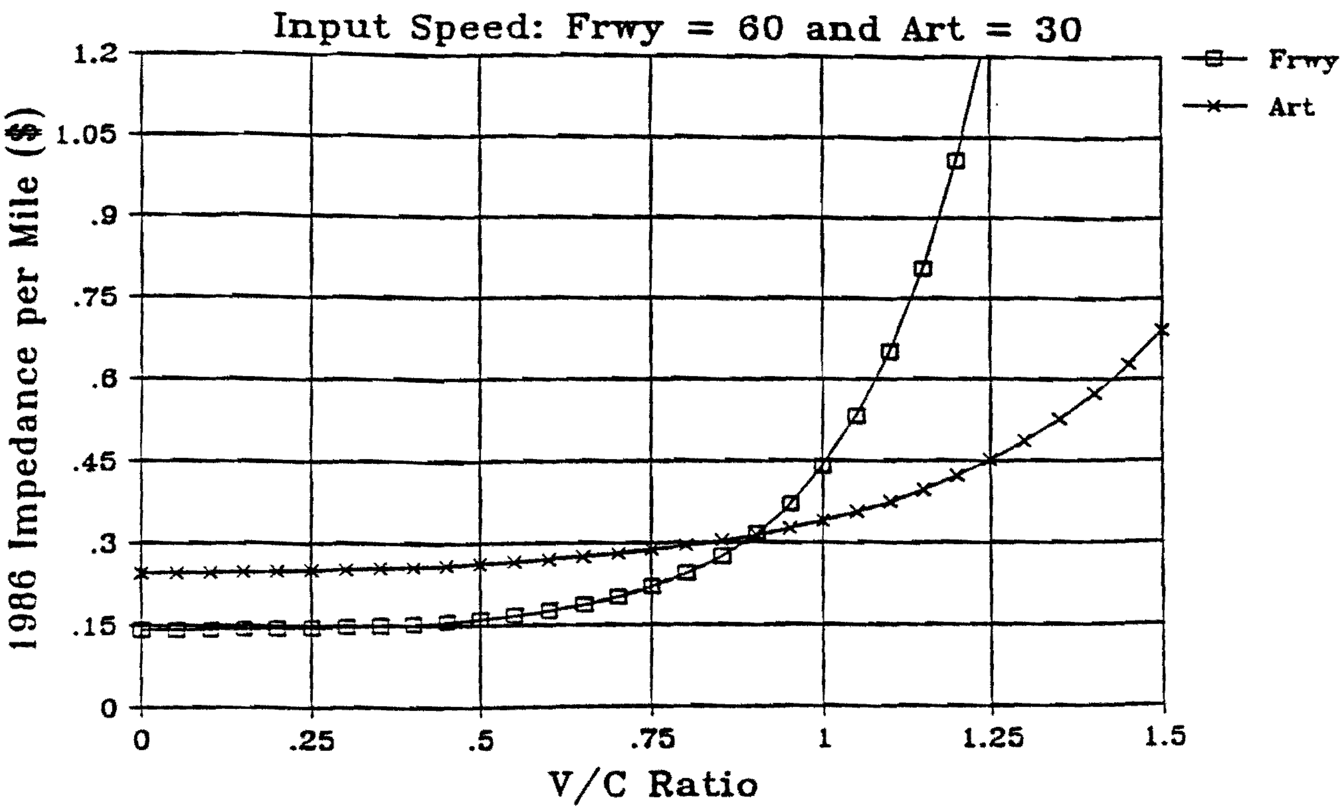

Figure 3. Dallas-Fort Worth Joint Model Impedance

V. 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 comparisons of the results using the different models and network parameters using macro-level measures. The comparisons using micro-level measures are presented in Chapter VI.

In reviewing the results presented in this chapter it should be remembered that all three regional assignments were performed using the same trip table. Likewise, all three subarea assignments were performed using the same subarea trip table. Hence, differences in the assignment results are directly attributable to differences in the paths to which the trips are assigned.

MACRO-LEVEL MEASURES

The macro-level measures compare aggregate measures of assigned versus counted volumes while 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 volumes across cutlines (i.e., corridor intercepts or screenlines). In the Dallas-Fort Worth networks, not all links have observed counts for comparison. The assigned versus counted comparisons, therefore, focus only on the subset of links with counted volumes.

VMT RESULTS

The VMT on a link are computed by multiplying the link's volume by the link's distance in miles. Both the assigned VMT and the counted VMT for the subset of links can computed and accumulated for comparison. For the VMT comparisons in this study, the links were cross-classified by functional class and by area type.

Table 18 summarizes the VMT assignment results for the three regional assignments performed. Table 18 shows that the Dallas-Fort Worth regional network consisted of 16,959 links (excluding centroid connectors). These 16,959 links include both links with counts and links without counts. While the subsequent comparisons will focus only subsets of links with counted volumes, it was felt that summaries should include a cross-classification of the total assigned VMT for each assignment. These data provide an indication of some general differences between the results using the different models and network assumptions. Some of the more interesting observations are:

- The Joint Model assigned more VMT on the 16,959 regional network links than either of the Texas Model applications. This was also true for the regional links stratified by area type.
- The CBD results using the Dallas-Fort Worth capacities and speeds were similar for both models. The Texas Model, using Houston-Galveston speeds and capacities were considerably different for most facility types.
- For freeways, the Texas Model using the Dallas-Fort Worth capacities generally produced the higher freeway VMT results than the Joint Model. This is probably largely attributable to differences in the speed adjustments in the two models. Interestingly, the Texas Model using the Houston-Galveston capacities and speed logic yielded generally lower freeway VMT results than the other two assignments. The shift in VMT results from the Texas Model with Dallas-Fort Worth capacities and speeds to the Texas Model results using the Houston-Galveston capacities and speeds is totally attributable to the differences in the input capacities and speeds.
- While the Texas Model (with Houston-Galveston capacities and speeds) provided somewhat lower VMT estimates, it also provided considerably lower VMT on the ramp links. This suggests that the trips diverted from the freeways were generally shorter trips. The higher VMT on the frontage roads suggests that some of these "shorter" trips stayed on the frontage roads.
- The Joint Model generally assigned more traffic to major arterials than either of the Texas Model assignments.
- The Texas Model with the Houston-Galveston capacity and speed inputs generally produced higher volume estimates on minor arterials.

In reviewing the VMT data in Table 18, it should be remembered that the regional assignments are used to evaluate the freeway system.

Table 19 summarizes the VMT assignment results for the three assignments performed for the East Dallas subarea. The subarea network summaries display results only for links within the focused subarea and <u>not</u> links outside the subarea being studied. As we can see from Table 19, the subarea portion of the East Dallas subarea network consisted of 1,900 links (excluding centroid connectors). These 1,900 links include both links with counts and links without counts. While the subsequent comparisons will focus only on subsets of links with counted volumes, it was felt that summaries should include a cross classification of the total assigned VMT for each assignment. These data provide an indication of some general differences between the results using the different models and network assumptions. In reviewing the results displayed in Table 19, it may be noted that:

- Again, the Joint Model assigned somewhat more VMT within the subarea than either Texas Model application.
- As may be observed from the totals column for the combined area types, the Texas Model with Houston-Galveston speeds and capacities provided generally lower VMT estimates for all facility types except minor arterials.
- In the urban residential area type, the Texas Model with Houston-Galveston speeds and capacities also provided the lowest VMT estimates on all facility types except minor arterials.

Table 20 presents the comparisons of assigned VMT to counted VMT for 4,866 links with counts in the regional network. The percentages were computed by dividing the assigned VMT by the assigned VMT for a given subset of links. Table 21 displays the comparisons for the 521 links with counts in the East Dallas subarea. In reviewing the results in Tables 20 and 21, it was noted that:

- Although varying by area type, both the Joint Model and the Texas Model with Houston-Galveston speeds and capacities generally provided better VMT estimates for freeways than the Texas Model with Dallas-Fort Worth capacities and speeds.
- The tendency to underestimate VMT on collectors using Houston-Galveston speeds and capacities suggests that either the initial speeds and/or capacities would need to be increased for collector streets for the Dallas-Fort Worth applications. If this were done, the increased VMT on collectors would likely

result in reduced VMT on the minor arterials and, hence, improve both facility types.

- The Texas Model with Dallas-Fort Worth speeds and capacities generally tended to overload the freeway links. The introduction of the 24-hour speeds and capacities which were more compatible with the Texas Model produced results which were very competitive with the calibrated model results from the Joint Model.

Recognizing that some assignment improvements would likely result from a refinement of the "borrowed" Houston-Galveston speeds and capacities, it was felt that neither model emerged as clearly superior from a VMT perspective.

Comparing the Joint Model and the Texas Model VMT results using a common set of input capacities and speeds provides an opportunity to see how the two models function. The following observations can be made from these comparisons:

- The Texas Model generally assigned more VMT to the freeways and less VMT on the non-freeway links. This is probably attributable to the differences in the speed adjustments and the use of travel costs rather than travel time in minimum path selection.
- While the freeway VMT increased using the Texas Model, the frontage road VMT decreased and the ramp VMT increased. This suggests that the Texas Model is probably assigning more short trips to the freeway which remained on the frontage roads using the Joint Model.

The comparison of the VMT results for the two Texas Model assignments using different input capacities and speeds provides an opportunity to see how these inputs affect the model's function. The following observations can be made from these comparisons:

- The freeway VMT estimates dropped substantially when the lower freeway speeds but higher freeway capacities were introduced in the first two area types. The 40 mph and 45 mph freeway speeds are apparently too low and tended to somewhat underload the freeways. Freeway speeds averaging 56 to 58 mph in the Dallas-Fort Worth speeds and capacities (even with lower capacities for these first two area types) resulted in over assignments using both models. The network average speeds were previously summarized in

Table 14.

- The Texas Model using the Houston speeds and capacities tended to substantially over-assign traffic to the minor arterial system. This is likely due to the use of substantially higher input speeds for minor arterials in the new speed set.

The analyses of the VMT results suggest the capacity restraint assignments are more sensitive to the basic network parameters of speed and capacity than the model selected for application. Surprisingly, the input speeds (particularly the relative differences between freeway speeds and arterial speeds) may have more impact on capacity restraint assignment results than the capacity estimates. This suggests that initial model calibration efforts should probably focus on input speed refinements using simple all-or-nothing assignments. The subsequent application of the capacity restraint model would then be used to further refine the model's results. It appeared that both the Joint Model and the Texas Model would benefit from improvements in the input speed estimates.

Table 18
Total VMT on the Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	37	173	652	703	402	1,967
Miles	8.8	63.1	299.0	400.3	322.0	1,093.1
Joint (D-FW Cap/Spd)	554,107	3,417,430	14,949,848	12,791,832	6,230,521	37,934,704
Texas (D-FW Cap/Spd)	542,128	3,682,314	15,804,463	14,141,837	6,773,619	40,934,320
Texas (H-G Cap/Spd)	362,989	2,976,403	13,516,304	12,072,811	6,170,102	35,089,744
Principal Arterials						
# Links	186	212	869	403	120	1,790
Miles	13.2	55.5	292.8	182.3	132.7	676.5
Joint (D-FW Cap/Spd)	107,616	1,196,769	6,484,223	3,389,527	1,732,231	12,910,100
Texas (D-FW Cap/Spd)	116,634	1,034,583	5,663,655	2,978,048	1,646,894	11,439,525
Texas (H-G Cap/Spd)	109,956	1,223,107	6,152,210	2,927,281	1,561,055	11,973,320
Minor Arterials						
# Links	310	305	1,614	1,108	414	3,751
Miles	24.7	67.7	583.8	534.5	414.5	1,624.9
Joint (D-FW Cap/Spd)	167,816	785,624	7,482,735	4,623,243	1,973,148	15,032,026
Texas (D-FW Cap/Spd)	161,431	652,336	6,241,898	3,797,793	1,691,950	12,544,883
Texas (H-G Cap/Spd)	208,411	1,036,707	8,445,047	5,045,307	2,151,802	16,886,592
Collectors						
# Links	191	226	2,316	1,742	1,489	5,964
Miles	11.9	66.9	847.2	866.4	1,357.4	3,149.6
Joint (D-FW Cap/Spd)	30,622	350,513	3,041,142	2,346,152	2,226,029	7,993,490
Texas (D-FW Cap/Spd)	28,723	273,878	2,213,008	1,533,058	1,687,877	5,735,758
Texas (H-G Cap/Spd)	32,445	229,237	1,894,246	1,187,118	1,789,692	5,131,900
Locals						
# Links	0	0	0	0	0	0
Ramps						
# Links	63	200	724	745	385	2,117
Miles	10.4	31.4	139.3	180.8	87.1	448.9
Joint (D-FW Cap/Spd)	215,407	331,377	1,087,209	759,756	176,699	2,569,898
Texas (D-FW Cap/Spd)	167,142	323,113	1,079,232	837,393	201,378	2,607,680
Texas (H-G Cap/Spd)	26,331	184,298	691,622	525,127	179,845	1,606,863
Frontage Roads						
# Links	40	109	501	472	248	1,370
Miles	5.6	31.4	199.6	257.6	179.4	673.6
Joint (D-FW Cap/Spd)	21,874	275,314	957,061	410,855	92,424	1,757,335
Texas (D-FW Cap/Spd)	19,754	205,867	855,301	392,827	94,006	1,567,591
Texas (H-G Cap/Spd)	16,154	180,034	824,590	541,326	260,273	1,822,138
TOTALS						
# Links	827	1,225	6,676	5,173	3,058	16,959
Miles	74.7	316.0	2,361.3	2,421.6	2,493.1	7,653.7
Joint (D-FW Cap/Spd)	1,097,428	6,356,601	33,975,696	24,309,584	12,430,478	78,111,856
Texas (D-FW Cap/Spd)	1,035,801	6,171,679	31,835,248	23,670,496	12,095,210	74,757,776
Texas (H-G Cap/Spd)	756,276	5,829,366	31,502,592	22,289,648	12,112,183	72,436,832

Table 19
Total VMT on the East Dallas Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	0	0	67	75	39	181
Miles			31.5	37.8	34.2	103.5
Joint (D-FW Cap/Spd)			1,685,515	1,098,977	596,804	3,381,246
Texas (D-FW Cap/Spd)			1,741,980	1,237,454	595,454	3,574,845
Texas (H-G Cap/Spd)			1,468,516	965,703	591,362	3,025,531
Principal Arterials						
# Links	0	0	89	40	10	139
Miles			28.5	13.3	7.8	49.6
Joint (D-FW Cap/Spd)			800,406	233,769	106,735	1,140,907
Texas (D-FW Cap/Spd)			725,529	231,765	93,593	1,050,886
Texas (H-G Cap/Spd)			706,721	231,528	90,433	1,028,682
Minor Arterials						
# Links	0	0	276	181	52	509
Miles			99.2	73.8	34.5	207.5
Joint (D-FW Cap/Spd)			1,550,913	561,570	196,633	2,309,018
Texas (D-FW Cap/Spd)			1,488,235	532,391	202,768	2,223,292
Texas (H-G Cap/Spd)			1,759,034	756,139	252,661	2,767,732
Collectors & Locals						
# Links	0	0	239	309	216	764
Miles			91.9	138.0	165.1	395.0
Joint (D-FW Cap/Spd)			207,995	314,177	365,651	887,819
Texas (D-FW Cap/Spd)			205,543	307,020	376,003	888,562
Texas (H-G Cap/Spd)			121,246	212,017	312,942	646,199
Ramps						
# Links	0	0	71	82	36	189
Miles			16.7	17.7	5.7	40.0
Joint (D-FW Cap/Spd)			136,600	75,048	22,694	234,339
Texas (D-FW Cap/Spd)			126,749	71,305	21,990	220,041
Texas (H-G Cap/Spd)			79,266	41,169	23,356	143,788
Frontage Roads						
# Links	0	0	47	39	32	118
Miles			21.7	23.6	24.2	69.5
Joint (D-FW Cap/Spd)			139,828	23,201	13,538	176,566
Texas (D-FW Cap/Spd)			117,522	27,540	20,226	165,286
Texas (H-G Cap/Spd)			70,476	42,342	49,864	162,680
TOTALS						
# Links	0	0	789	726	385	1,900
Miles			289.6	304.2	271.4	865.0
Joint (D-FW Cap/Spd)			4,521,042	2,306,543	1,302,038	8,129,411
Texas (D-FW Cap/Spd)			4,405,355	2,407,285	1,310,015	8,122,454
Texas (H-G Cap/Spd)			4,205,056	2,248,724	1,320,599	7,774,175

Table 20
Assigned versus Counted VMT on the Dallas-Fort Worth Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	3	39	179	216	136	573
Miles	.8	18.6	103.8	165.2	153.7	442.1
Counted	16,338	1,111,412	5,208,917	5,118,997	2,587,132	14,042,740
Joint (D-FW Cap/Spd)	167.9%	101.9%	103.2%	104.9%	122.7%	107.4%
Texas (D-FW Cap/Spd)	147.7%	111.0%	108.4%	117.3%	134.3%	116.7%
Texas (H-G Cap/Spd)	83.7%	88.3%	91.7%	99.5%	120.4%	99.5%
Principal Arterials						
# Links	60	72	365	171	73	741
Miles	4.5	23.8	156.4	104.0	95.3	384.1
Counted	69,230	655,998	3,963,187	2,042,939	1,376,317	8,107,536
Joint (D-FW Cap/Spd)	42.1%	81.4%	89.8%	91.0%	94.3%	89.8%
Texas (D-FW Cap/Spd)	53.5%	71.0%	77.2%	80.0%	86.8%	78.8%
Texas (H-G Cap/Spd)	55.0%	83.5%	83.5%	79.1%	82.3%	81.9%
Minor Arterials						
# Links	115	117	652	488	229	1,601
Miles	10.6	32.1	291.1	297.6	282.6	913.9
Counted	85,977	531,331	4,928,521	3,210,212	1,344,083	10,099,865
Joint (D-FW Cap/Spd)	89.4%	77.1%	79.7%	86.3%	101.3%	84.6%
Texas (D-FW Cap/Spd)	88.1%	66.9%	66.0%	71.7%	87.0%	70.8%
Texas (H-G Cap/Spd)	111.0%	103.8%	87.1%	91.6%	113.8%	93.2%
Collectors						
# Links	49	45	437	433	619	1,583
Miles	3.8	17.6	202.5	307.7	760.6	1,292.1
Counted	18,777	141,428	1,526,461	1,373,540	1,610,588	4,670,415
Joint (D-FW Cap/Spd)	45.7%	86.1%	68.6%	83.6%	87.3%	79.9%
Texas (D-FW Cap/Spd)	51.1%	76.0%	53.8%	60.9%	68.6%	61.7%
Texas (H-G Cap/Spd)	58.9%	62.7%	42.5%	45.0%	68.2%	52.7%
Locals						
# Links	0	0	0	0	0	0
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	9	22	106	140	91	368
Miles	1.0	8.4	56.7	101.5	82.1	249.8
Counted	6,949	81,957	291,396	298,146	117,183	795,628
Joint (D-FW Cap/Spd)	33.2%	88.2%	79.8%	47.5%	48.7%	63.6%
Texas (D-FW Cap/Spd)	32.8%	71.7%	70.9%	46.8%	46.0%	57.9%
Texas (H-G Cap/Spd)	34.2%	56.0%	72.1%	73.5%	106.3%	75.7%
TOTALS						
# Links	236	295	1,739	1,448	1,148	4,866
Miles	20.8	100.5	810.4	976.0	1,374.3	3,282.0
Counted	197,267	2,522,039	15,918,219	12,043,544	7,035,013	37,694,112
Joint (D-FW Cap/Spd)	73.2%	90.0%	88.8%	93.7%	103.7%	93.2%
Texas (D-FW Cap/Spd)	75.4%	88.1%	81.6%	90.6%	99.5%	88.2%
Texas (H-G Cap/Spd)	81.4%	87.8%	83.1%	87.1%	99.5%	87.7%

Table 21
Assigned versus Counted VMT on the East Dallas Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	0	0	22	19	12	53
Miles			12.3	13.7	18.5	44.5
Counted			640,289	428,936	343,231	1,412,448
Joint (D-FW Cap/Spd)			111.8%	103.4%	96.4%	105.5%
Texas (D-FW Cap/Spd)			115.7%	113.6%	97.8%	110.7%
Texas (H-G Cap/Spd)			95.4%	88.4%	98.2%	94.0%
Principal Arterials						
# Links	0	0	43	16	6	65
Miles			14.7	7.7	6.0	28.3
Counted			376,821	114,576	89,792	581,189
Joint (D-FW Cap/Spd)			114.9%	93.2%	91.7%	107.0%
Texas (D-FW Cap/Spd)			104.2%	100.3%	80.9%	99.8%
Texas (H-G Cap/Spd)			104.5%	107.4%	78.2%	101.0%
Minor Arterials						
# Links	0	0	106	80	26	212
Miles			46.1	43.2	20.8	110.0
Counted			725,086	363,126	150,929	1,239,123
Joint (D-FW Cap/Spd)			100.9%	95.0%	103.1%	99.4%
Texas (D-FW Cap/Spd)			93.9%	88.7%	107.8%	94.1%
Texas (H-G Cap/Spd)			110.1%	125.4%	128.1%	116.8%
Collectors & Locals						
# Links	0	0	24	67	63	154
Miles			11.3	44.8	82.4	138.4
Counted			51,670	140,648	153,709	346,025
Joint (D-FW Cap/Spd)			80.7%	88.7%	147.9%	113.8%
Texas (D-FW Cap/Spd)			90.2%	91.9%	154.5%	119.5%
Texas (H-G Cap/Spd)			48.1%	58.1%	118.5%	83.5%
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	0	0	12	15	10	37
Miles			7.7	13.0	10.8	31.5
Counted			33,033	29,710	14,713	77,456
Joint (D-FW Cap/Spd)			198.8%	28.1%	49.4%	104.9%
Texas (D-FW Cap/Spd)			149.9%	44.4%	93.0%	98.6%
Texas (H-G Cap/Spd)			91.8%	80.6%	230.4%	113.8%
TOTALS						
# Links	0	0	207	197	117	521
Miles			92.0	122.4	138.4	352.8
Counted			1,826,846	1,076,993	752,372	3,656,102
Joint (D-FW Cap/Spd)			108.8%	95.5%	106.8%	104.5%
Texas (D-FW Cap/Spd)			104.5%	99.1%	109.3%	103.9%
Texas (H-G Cap/Spd)			101.7%	98.7%	108.6%	102.3%

CUTLINE RESULTS

Table 22 summarizes the comparisons of assigned cutline volumes to the counted cutline volumes for the regional network's cutlines used with the Joint Model applications. Unfortunately, as may be noted from the data displayed, not all of the links comprising the cutline have 1986 counts. Hence, the presentation of the results focused on the subset of each cutline's links for which count data were available. The percentages were computed by dividing the sum of the assigned volumes on the links with counts by the sum of the counted volumes on the same links. Table 23 presents the results for the East Dallas subarea cutlines. A few of the subarea's cutline links are actually just outside of the subarea.

The Joint Model results compared more favorably to counts on 39 of the 104 cutlines, while the Texas Model with Dallas-Fort Worth capacities and counts compared more favorably to counts on 37 of the 104 cutlines. In view of the VMT results, it was surprising to see the Texas Model with the Houston capacities comparing more favorably to counts on only 28 of the 104 cutlines.

Table 22
Cutline Results for the Dallas-Fort Worth Regional Assignments

				Assigned Volume as % of Count (for links with counts only)		
Cutline Number	Total Links	Links with Counts	Total Counted Volume	Joint Model with D-FW Capacities & Speeds	Texas Model with D-FW Capacities & Speeds	Texas Model with H-G Capacities & Speeds
1	10	5	55,762	109.9	83.5	76.5
2	8	5	54,336	87.9	113.3	151.4
4	10	9	81,145	75.2	79.5	110.3
5	3	2	44,036	101.5	99.4	171.2
6	15	8	309,645	106.0	114.3	88.5
7	13	10	258,694	100.6	97.8	94.8
8	16	11	362,184	111.7	105.2	85.8
9	44	13	171,820	112.6	106.8	112.4
10	18	8	183,368	116.3	105.6	113.2
11	8	3	231,243	95.7	98.7	84.2
12	22	12	360,831	91.8	82.9	89.5
13	13	7	156,949	95.0	85.9	89.8
14	13	3	28,518	122.7	102.3	182.9
15	26	6	207,172	82.6	97.7	98.6
16	5	2	61,224	87.6	83.5	45.1
17	14	5	242,915	105.9	105.3	95.8
18	7	3	178,921	103.6	96.7	88.2
19	3	1	21,771	94.1	90.6	112.8
20	5	2	89,086	112.4	103.1	94.0
21	26	7	91,325	110.1	104.5	130.3
22	10	7	211,578	100.2	106.2	84.5
23	2	2	121,456	102.2	106.3	87.4
24	13	4	51,458	82.2	48.9	79.2
25	34	20	323,103	88.8	88.4	87.1
26	22	11	220,573	91.8	105.5	82.7
27	31	13	146,899	100.7	104.9	87.5
28	19	10	227,635	96.3	93.5	89.3
29	13	6	299,204	95.4	92.1	71.0
30	12	7	243,215	79.1	83.4	77.2
31	20	5	139,636	112.4	106.3	91.1
32	7	2	77,407	124.7	94.9	116.2
33	8	2	24,312	39.2	34.8	78.4
34	7	3	91,657	78.6	75.7	80.5
35	23	12	351,625	98.5	105.1	73.5
36	18	9	290,432	88.6	91.6	80.1
37	17	8	72,660	104.2	130.8	107.2
38	22	12	231,658	86.2	79.3	80.5
39	23	5	89,996	98.0	82.2	107.8
40	17	9	246,388	96.3	87.8	87.1
41	25	7	128,424	86.6	73.3	89.0
42	30	16	214,116	119.8	113.4	102.9
50	3	3	36,463	168.6	149.5	123.9
51	9	5	24,800	64.4	63.3	110.4
52	7	2	5,544	.2	.0	30.1
53	12	6	42,736	61.7	62.7	107.1
54	6	2	98,025	106.2	102.6	82.4

Table 22 (Continued)
Cutline Results for the Dallas-Fort Worth Regional Assignments

Cutline Number	Total Links	Links with Counts	Total Counted Volume	Assigned Volume as % of Count (for links with counts only): Joint Model with D-FW Capacities & Speeds	Texas Model with D-FW Capacities & Speeds	Texas Model with H-G Capacities & Speeds
55	2	2	92,194	88.2	103.0	74.6
56	3	2	20,695	50.9	62.2	91.3
57	4	1	14,493	104.0	88.1	15.0
58	7	7	142,511	95.8	99.1	101.9
59	12	11	53,109	91.0	100.4	102.3
61	14	8	66,645	90.4	65.0	71.2
62	20	8	222,126	119.4	95.9	92.4
63	2	2	64,712	89.9	92.2	80.9
64	10	7	110,427	91.5	99.9	83.8
65	19	8	106,364	82.3	60.7	88.5
66	4	1	5,619	82.6	39.1	105.6
67	4	3	88,977	84.0	68.1	70.1
68	24	12	175,187	100.4	83.2	83.7
69	7	5	97,858	67.0	59.5	73.6
70	9	4	63,813	179.6	122.5	139.4
71	8	1	34,418	131.9	78.5	110.1
72	15	9	145,027	96.5	78.7	94.5
73	8	2	21,646	74.2	70.2	124.4
74	8	2	14,152	43.8	28.8	62.1
75	20	9	101,351	81.1	68.8	89.0
76	12	4	27,185	170.3	156.2	160.4
77	8	8	88,796	106.0	108.2	95.0
78	7	6	127,614	91.8	82.3	82.7
79	8	7	112,850	84.5	80.6	96.4
80	9	3	55,673	89.0	94.5	82.2
81	19	7	124,708	85.3	73.4	84.9
82	12	7	126,511	111.8	98.0	97.7
83	20	14	223,608	100.1	102.6	91.9
84	19	8	118,541	110.9	100.4	99.2
85	15	9	165,596	89.4	87.8	89.4
86	18	9	205,851	105.1	87.0	74.3
87	24	17	231,818	73.4	67.1	65.1
88	36	20	412,070	117.3	119.6	111.1
90	31	24	187,847	108.8	106.3	104.8
All	1,134	557	11,051,937	98.5	94.5	90.7

Table 23
Cutline Results for East Dallas Subarea Assignments

Cutline Number	Total Links	Links with Counts	Total Counted Volume	Assigned Volume as % of Count (for links with counts only): Joint Model with D-FW Capacities & Speeds	Texas Model with D-FW Capacities & Speeds	Texas Model with H-G Capacities & Speeds
1	4	3	30,126	94.7	113.6	122.4
2	4	4	30,813	101.3	79.3	74.5
3	7	4	89,720	96.6	95.1	94.9
4	12	5	77,943	106.8	99.2	110.5
5	4	4	13,499	121.8	136.4	147.6
6	4	3	68,595	106.0	87.9	94.1
7	11	6	73,071	73.8	92.0	116.5
8	3	3	31,071	132.8	118.0	132.4
9	5	5	66,270	120.6	122.1	135.7
10	2	2	28,439	114.3	109.4	136.0
11	4	2	50,796	109.3	101.3	119.6
12	4	3	57,694	66.4	64.2	106.2
13	4	3	43,566	107.2	104.4	109.3
14	5	4	59,893	98.7	78.6	104.8
15	14	4	121,104	105.7	91.5	102.5
16	9	6	76,441	106.1	94.4	84.4
17	3	3	47,083	108.6	106.8	89.1
18	3	3	40,369	93.3	93.7	76.2
19	8	4	54,282	118.5	111.2	144.7
20	4	3	34,550	88.9	83.5	113.7
21	5	4	30,206	121.4	119.2	118.4
22	5	4	44,392	69.7	53.8	80.7
23	4	4	19,857	70.5	74.3	73.9
24	6	4	101,748	129.7	111.2	112.6
All	134	90	1,291,528	103.2	96.4	107.1

VI. 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 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 comparisons of the results using the different models and network parameters using micro-level measures. The comparisons using macro-level measures are presented in Chapter V.

In reviewing the results presented in this chapter it should be remembered that all three regional assignments were performed using the same trip table. Likewise, all three subarea assignments were performed using the same subarea trip table. Hence, differences in the assignment results are directly attributable to differences in the paths to which the trips are assigned.

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. Again, these comparisons focus only on the subset of links with counted volumes.

The following are the computational formulas used in estimating the micro-measures for each subset of links:

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

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

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

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

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

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

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 24 summarizes the percent mean differences for the counted volume links in the regional network stratified by volume group and area type. In reviewing the regional network results, it may be noted that:

- There was a general tendency toward under-assignment in all three assignments. This tendency can also be observed in the VMT results in Table 20.
- The Texas Model with the Houston Capacities and speeds seemed to have a greater tendency toward under-assignment for the links with counts greater than 50,000 than did the Texas Model with the Dallas-Fort Worth capacities or the Joint Model.
- For the links with counted volumes of 50,000 and above, the Texas Model with the Dallas-Fort Worth capacities seemed to have produced slightly better results than the Joint Model.

The percent mean difference results by volume group for the East Dallas subarea network are presented in Table 25. In reviewing the subarea network results in Table 25, it may be noted that:

- Again, the Texas Model with the Houston Capacities and speeds seemed to have a greater tendency toward under-assignment for the higher volume links (i.e., links with counts greater than 30,000) than did either the Texas Model with the Dallas-Fort Worth capacities or the Joint Model.
- For the very low volume links (i.e., less than 10,000 vpd), the Texas Model with the Houston Capacities and speeds seemed to have a greater tendency toward over-assignment than did either the Texas Model with the Dallas-Fort Worth capacities or the Joint Model.
- Both the Joint Model and the Texas Model with Dallas-Fort Worth capacities produced exceptionally comparable results for and average percent difference perspective.

It is interesting to first compare the two Texas Model application results for each network and then to compare the Joint Model and Texas Model results using common input speeds and capacities. The differences attributable to the use of various input speeds and capacities with the same model (i.e., the Texas Model) were generally greater than the differences in the two models using a common set of input speeds and capacities.

Table 26 summarizes the percent mean differences for the regional network stratified by functional class and area type. In reviewing the regional network results, it may be noted that:

- While the freeway results by area type vary by model, the Texas Model with the Houston-Galveston capacities and input speeds produced slightly better overall results for freeways than the Joint Model.
- Again, while the freeway results by area type vary by model, the Texas Model with the Houston-Galveston capacities had a slight tendency toward under-assignment. This is particularly surprising since the freeway speed adjustment curve for the Texas Model is remarkably flatter than the Joint Model's (refer to Figures 1 and 2). In contrast, both the Joint Model and the Texas Model with the Dallas-Fort Worth capacities and input speeds had a tendency toward over-assignment. Again, the differences in the input capacities and speeds seemed to have more impact on assignment results than model differences.

The percent mean difference results by functional class and area type for the East Dallas subarea network are displayed in Table 27. These results were consistent with observed results from the preceding tables in this chapter and the VMT results in Chapter V.

Table 24
Average Percent Differences by Volume Group and Area Type for Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Count: Under 5,000						
# Links	74	21	232	496	742	1,565
Avg Count	3,191.4	3,655.5	2,956.6	2,472.8	1,745.4	2,249.5
Joint (D-FW Cap/Spd)	-24.7%	15.8%	-.1%	14.4%	-6.1%	1.4%
Texas (D-FW Cap/Spd)	-25.6%	-5.4%	-20.0%	-10.1%	-25.0%	-18.4%
Texas (H-G Cap/Spd)	25.7%	28.6%	-22.3%	-1.2%	6.9%	.1%
Count: 5,000 to 10,000						
# Links	83	65	339	280	196	963
Avg Count	7,483.3	7,350.1	7,391.8	7,082.0	7,080.3	7,243.4
Joint (D-FW Cap/Spd)	-11.4%	-20.8%	-15.4%	-11.6%	-15.7%	-14.4%
Texas (D-FW Cap/Spd)	-15.3%	-19.8%	-35.3%	-28.8%	-16.6%	-26.9%
Texas (H-G Cap/Spd)	5.5%	22.0%	-22.3%	-14.6%	-9.7%	-12.1%
Count: 10,000 to 20,000						
# Links	65	95	529	365	151	1,205
Avg Count	13,741.9	14,828.6	14,950.1	14,645.8	14,124.6	14,679.7
Joint (D-FW Cap/Spd)	-31.7%	-36.7%	-18.1%	-17.8%	.8%	-17.9%
Texas (D-FW Cap/Spd)	-30.8%	-44.5%	-30.5%	-25.6%	1.3%	-26.3%
Texas (H-G Cap/Spd)	-22.8%	-8.6%	-13.4%	-16.9%	-7.4%	-13.8%
Count: 20,000 to 30,000						
# Links	11	44	292	160	42	549
Avg Count	21,754.0	24,668.1	24,605.8	24,349.8	24,180.3	24,446.5
Joint (D-FW Cap/Spd)	-53.0%	-8.4%	-17.4%	-13.9%	7.5%	-14.4%
Texas (D-FW Cap/Spd)	-51.4%	-1.4%	-24.2%	-14.9%	9.2%	-17.6%
Texas (H-G Cap/Spd)	-57.7%	13.7%	-15.4%	-16.7%	.6%	-12.9%
Count: 30,000 to 40,000						
# Links	2	30	186	94	12	324
Avg Count	30,615.5	36,137.1	33,667.9	34,721.4	33,026.2	34,159.6
Joint (D-FW Cap/Spd)	-24.4%	-18.6%	-12.9%	-2.0%	26.7%	-8.9%
Texas (D-FW Cap/Spd)	-41.0%	-25.9%	-21.0%	2.3%	27.7%	-13.0%
Texas (H-G Cap/Spd)	-31.5%	-16.8%	-17.7%	-10.4%	11.5%	-14.5%
Count: 40,000 to 50,000						
# Links	0	7	64	30	4	105
Avg Count		43,815.6	43,871.1	44,327.7	41,991.3	43,926.3
Joint (D-FW Cap/Spd)		-14.5%	-5.2%	6.2%	28.1%	-1.3%
Texas (D-FW Cap/Spd)		-28.3%	-11.1%	12.3%	28.8%	-4.0%
Texas (H-G Cap/Spd)		-13.5%	-18.6%	-3.2%	5.9%	-12.9%
Count: 50,000 to 75,000						
# Links	1	22	76	20	1	120
Avg Count	62,212.0	61,504.1	61,234.6	56,831.1	51,000.0	60,472.9
Joint (D-FW Cap/Spd)	39.3%	-9.0%	-2.2%	10.5%	16.5%	-1.0%
Texas (D-FW Cap/Spd)	12.6%	-15.8%	-3.2%	10.3%	24.4%	-3.1%
Texas (H-G Cap/Spd)	-90.4%	-28.2%	-12.1%	-2.6%	-5.3%	-14.2%
Count: 75,000 to 100,000						
# Links	0	6	11	0	0	17
Avg Count		92,520.3	80,959.9			85,040.1
Joint (D-FW Cap/Spd)		12.3%	8.6%			10.0%
Texas (D-FW Cap/Spd)		10.5%	7.7%			8.8%
Texas (H-G Cap/Spd)		-8.7%	-9.5%			-9.2%
Count: 100,000 and above						
# Links	0	5	10	3	0	18
Avg Count		113,057.4	109,376.3	107,067.0		110,013.9
Joint (D-FW Cap/Spd)		3.5%	-8.1%	-.6%		-3.5%
Texas (D-FW Cap/Spd)		8.5%	-2.4%	1.2%		1.3%
Texas (H-G Cap/Spd)		-16.2%	-21.7%	-18.6%		-19.6%
ALL COUNTED LINKS						
# Links	236	295	1,739	1,448	1,148	4,866
Avg Count	8,954.4	23,433.8	19,547.7	12,778.1	5,615.4	13,968.1
Joint (D-FW Cap/Spd)	-25.1%	-14.1%	-12.2%	-7.6%	-.7%	-10.4%
Texas (D-FW Cap/Spd)	-27.0%	-17.6%	-20.3%	-12.4%	-4.1%	-16.5%
Texas (H-G Cap/Spd)	-15.2%	-8.5%	-15.9%	-12.6%	-2.2%	-12.9%

Table 25
Average Percent Differences by Volume Group and Area Type for the Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Count: Under 5,000						
# Links	0	0	25	92	74	191
Avg Count			2,972.2	2,699.7	1,744.5	2,365.3
Joint (D-FW Cap/Spd)			82.4%	-4.9%	37.2%	21.5%
Texas (D-FW Cap/Spd)			60.7%	3.9%	54.2%	27.6%
Texas (H-G Cap/Spd)			17.1%	19.9%	53.6%	29.1%
Count: 5,000 to 10,000						
# Links	0	0	34	38	16	88
Avg Count			7,260.8	6,859.3	7,774.2	7,180.8
Joint (D-FW Cap/Spd)			4.1%	-6.3%	-10.7%	-3.1%
Texas (D-FW Cap/Spd)			7.8%	-9.6%	6.7%	.4%
Texas (H-G Cap/Spd)			19.7%	22.1%	8.4%	18.5%
Count: 10,000 to 20,000						
# Links	0	0	64	45	20	129
Avg Count			15,216.0	14,348.5	15,813.1	15,005.9
Joint (D-FW Cap/Spd)			14.0%	-8.2%	-6.2%	3.3%
Texas (D-FW Cap/Spd)			5.5%	-10.4%	-17.3%	-3.5%
Texas (H-G Cap/Spd)			12.5%	4.1%	-16.7%	4.9%
Count: 20,000 to 30,000						
# Links	0	0	39	13	7	59
Avg Count			24,525.9	23,591.8	21,947.9	24,014.3
Joint (D-FW Cap/Spd)			1.6%	-3.9%	-2.0%	.0%
Texas (D-FW Cap/Spd)			-3.5%	-6.3%	-5.0%	-4.3%
Texas (H-G Cap/Spd)			10.7%	2.2%	-7.2%	6.9%
Count: 30,000 to 40,000						
# Links	0	0	29	5	0	34
Avg Count			33,175.8	34,097.2		33,311.3
Joint (D-FW Cap/Spd)			2.6%	9.6%		3.7%
Texas (D-FW Cap/Spd)			-5.4%	21.6%		-1.3%
Texas (H-G Cap/Spd)			-3.7%	-8.3%		-4.4%
Count: 40,000 to 50,000						
# Links	0	0	6	2	0	8
Avg Count			41,229.3	43,948.5		41,909.1
Joint (D-FW Cap/Spd)			13.9%	-15.7%		6.2%
Texas (D-FW Cap/Spd)			15.3%	4.7%		12.5%
Texas (H-G Cap/Spd)			7.0%	-26.0%		-1.7%
Count: 50,000 to 75,000						
# Links	0	0	8	2	0	10
Avg Count			67,274.3	51,385.5		64,096.5
Joint (D-FW Cap/Spd)			3.5%	-6.7%		1.9%
Texas (D-FW Cap/Spd)			9.3%	7.6%		9.0%
Texas (H-G Cap/Spd)			-16.2%	-24.3%		-17.5%
Count: 75,000 to 100,000						
# Links	0	0	2	0	0	2
Avg Count			78,746.0			78,746.0
Joint (D-FW Cap/Spd)			16.8%			16.8%
Texas (D-FW Cap/Spd)			14.5%			14.5%
Texas (H-G Cap/Spd)			-11.5%			-11.5%
Count: 100,000 and above						
# Links	0	0	0	0	0	0
ALL COUNTED LINKS						
# Links	0	0	207	197	117	521
Avg Count			20,080.5	9,251.5	6,182.7	12,864.9
Joint (D-FW Cap/Spd)			7.9%	-5.4%	1.7%	3.6%
Texas (D-FW Cap/Spd)			3.4%	-2.9%	2.2%	1.6%
Texas (H-G Cap/Spd)			3.9%	4.3%	2.2%	3.8%

Table 26
Average Percent Differences by Functional Class and Area Type for Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	3	39	179	216	136	573
Avg Count	31,710.7	63,632.9	51,814.7	31,714.0	16,265.2	36,499.0
Joint (D-FW Cap/Spd)	53.6%	.4%	2.6%	6.8%	20.3%	5.8%
Texas (D-FW Cap/Spd)	30.1%	6.4%	6.8%	17.7%	32.6%	13.2%
Texas (H-G Cap/Spd)	-53.5%	-15.6%	-9.4%	-.3%	19.7%	-4.3%
Principal Arterials						
# Links	60	72	365	171	73	741
Avg Count	14,285.6	26,683.1	26,061.5	19,494.2	15,872.2	22,649.1
Joint (D-FW Cap/Spd)	-52.2%	-18.7%	-10.6%	-10.7%	-7.2%	-13.4%
Texas (D-FW Cap/Spd)	-44.9%	-26.1%	-23.0%	-20.7%	-13.5%	-23.3%
Texas (H-G Cap/Spd)	-45.8%	-7.3%	-14.1%	-17.7%	-17.9%	-15.9%
Minor Arterials						
# Links	115	117	652	488	229	1,601
Avg Count	7,647.9	16,074.0	17,130.3	11,783.6	6,042.7	13,156.3
Joint (D-FW Cap/Spd)	2.2%	-24.1%	-19.6%	-15.9%	-4.8%	-17.1%
Texas (D-FW Cap/Spd)	-7.3%	-34.5%	-32.6%	-30.8%	-17.6%	-30.2%
Texas (H-G Cap/Spd)	25.5%	10.1%	-10.2%	-8.9%	6.2%	-5.4%
Collectors						
# Links	49	45	437	433	619	1,583
Avg Count	4,041.4	8,548.3	7,809.8	4,827.4	2,449.4	4,802.3
Joint (D-FW Cap/Spd)	-52.2%	-38.3%	-31.7%	-18.8%	-14.8%	-25.7%
Texas (D-FW Cap/Spd)	-50.7%	-40.3%	-45.6%	-38.9%	-31.1%	-40.7%
Texas (H-G Cap/Spd)	-28.3%	-37.6%	-54.6%	-52.1%	-28.0%	-47.0%
Locals						
# Links	0	0	0	0	0	0
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	9	22	106	140	91	368
Avg Count	9,270.8	11,125.5	5,889.1	3,415.9	1,931.9	4,365.4
Joint (D-FW Cap/Spd)	-58.6%	-10.4%	-16.0%	-44.5%	-66.9%	-31.4%
Texas (D-FW Cap/Spd)	-60.5%	-28.2%	-26.4%	-47.6%	-62.7%	-38.7%
Texas (H-G Cap/Spd)	-56.7%	-44.3%	-29.9%	-24.7%	-17.7%	-30.6%
TOTALS						
# Links	236	295	1,739	1,448	1,148	4,866
Avg Count	8,954.4	23,433.8	19,547.7	12,778.1	5,615.4	13,968.1
Joint (D-FW Cap/Spd)	-25.1%	-14.1%	-12.2%	-7.6%	-.7%	-10.4%
Texas (D-FW Cap/Spd)	-27.0%	-17.6%	-20.3%	-12.4%	-4.1%	-16.5%
Texas (H-G Cap/Spd)	-15.2%	-8.5%	-15.9%	-12.6%	-2.2%	-12.9%

Table 27
Average Percent Differences by Functional Class and Area Type for Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	0	0	22	19	12	53
Avg Count			50,877.5	30,335.8	18,783.9	36,247.0
Joint (D-FW Cap/Spd)			11.6%	4.5%	-2.6%	7.8%
Texas (D-FW Cap/Spd)			15.5%	14.3%	-4.7%	12.8%
Texas (H-G Cap/Spd)			-4.4%	-10.9%	-2.9%	-6.2%
Principal Arterials						
# Links	0	0	43	16	6	65
Avg Count			26,049.7	14,746.3	15,478.7	22,291.5
Joint (D-FW Cap/Spd)			16.4%	-9.0%	-5.6%	10.8%
Texas (D-FW Cap/Spd)			5.1%	-3.5%	-18.2%	2.2%
Texas (H-G Cap/Spd)			6.3%	7.9%	-22.1%	4.8%
Minor Arterials						
# Links	0	0	106	80	26	212
Avg Count			16,451.7	9,196.5	8,031.5	12,681.2
Joint (D-FW Cap/Spd)			-.2%	-5.3%	2.7%	-1.4%
Texas (D-FW Cap/Spd)			-5.5%	-11.0%	2.4%	-6.4%
Texas (H-G Cap/Spd)			11.5%	30.3%	22.4%	17.5%
Collectors & Locals						
# Links	0	0	24	67	63	154
Avg Count			4,844.8	3,524.1	2,905.5	3,476.9
Joint (D-FW Cap/Spd)			-11.4%	-17.5%	13.3%	-5.6%
Texas (D-FW Cap/Spd)			-4.1%	-12.6%	22.3%	1.2%
Texas (H-G Cap/Spd)			-43.6%	-40.4%	-11.0%	-31.0%
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	0	0	12	15	10	37
Avg Count			4,755.8	2,560.0	1,323.2	2,937.9
Joint (D-FW Cap/Spd)			54.8%	-58.5%	-51.1%	1.9%
Texas (D-FW Cap/Spd)			24.8%	-43.3%	-19.0%	-4.6%
Texas (H-G Cap/Spd)			-18.7%	-12.9%	122.0%	.5%
TOTALS						
# Links	0	0	207	197	117	521
Avg Count			20,080.5	9,251.5	6,182.7	12,864.9
Joint (D-FW Cap/Spd)			7.9%	-5.4%	1.7%	3.6%
Texas (D-FW Cap/Spd)			3.4%	-2.9%	2.2%	1.6%
Texas (H-G Cap/Spd)			3.9%	4.3%	2.2%	3.8%

PERCENT STANDARD DEVIATION OF THE DIFFERENCES

Tables 28 and 29 summarize the percent standard deviation of the differences for the links stratified by volume group and area type in the two networks. In reviewing the results in these two tables, it may be observed that:

- As expected the percent standard deviation tend to generally decrease with increases in the counted volumes.
- The percent standard deviations of the differences were surprisingly consistent for all three models.

Tables 30 and 31 summarize the percent standard deviation of the differences for the links stratified by functional class and area type in the two networks. In reviewing the results in these two tables, 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 have the higher volumes.
- Again, the percent standard deviation of the differences were surprisingly consistent for all three models.

Table 28
Percent Standard Deviation by Volume Group and Area Type for Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Count: Under 5,000						
# Links	74	21	232	496	742	1,565
Avg Count	3,191.4	3,655.5	2,956.6	2,472.8	1,745.4	2,249.5
Joint (D-FW Cap/Spd)	114.0%	123.5%	128.1%	143.8%	123.3%	135.4%
Texas (D-FW Cap/Spd)	87.7%	105.0%	128.6%	131.7%	113.4%	125.1%
Texas (H-G Cap/Spd)	132.9%	120.6%	118.1%	132.9%	119.4%	129.5%
Count: 5,000 to 10,000						
# Links	83	65	339	280	196	963
Avg Count	7,483.3	7,350.1	7,391.8	7,082.0	7,080.3	7,243.4
Joint (D-FW Cap/Spd)	91.0%	63.6%	88.9%	79.9%	66.3%	80.9%
Texas (D-FW Cap/Spd)	67.7%	63.4%	68.6%	65.3%	61.3%	66.3%
Texas (H-G Cap/Spd)	75.2%	92.1%	83.4%	73.9%	63.7%	78.0%
Count: 10,000 to 20,000						
# Links	65	95	529	365	151	1,205
Avg Count	13,741.9	14,828.6	14,950.1	14,645.8	14,124.6	14,679.7
Joint (D-FW Cap/Spd)	70.8%	52.4%	54.9%	50.5%	37.0%	53.2%
Texas (D-FW Cap/Spd)	49.4%	42.8%	46.3%	45.6%	38.0%	46.5%
Texas (H-G Cap/Spd)	56.5%	61.8%	50.8%	43.0%	34.2%	48.3%
Count: 20,000 to 30,000						
# Links	11	44	292	160	42	549
Avg Count	21,754.0	24,668.1	24,605.8	24,349.8	24,180.3	24,446.5
Joint (D-FW Cap/Spd)	44.5%	37.1%	40.0%	34.8%	27.9%	38.4%
Texas (D-FW Cap/Spd)	28.1%	54.9%	35.2%	42.7%	33.6%	40.5%
Texas (H-G Cap/Spd)	19.5%	48.2%	38.9%	31.3%	27.1%	38.1%
Count: 30,000 to 40,000						
# Links	2	30	186	94	12	324
Avg Count	30,615.5	36,137.1	33,667.9	34,721.4	33,026.2	34,159.6
Joint (D-FW Cap/Spd)	107.4%	25.6%	31.5%	29.1%	25.4%	31.6%
Texas (D-FW Cap/Spd)	34.4%	22.4%	29.0%	33.3%	42.6%	33.0%
Texas (H-G Cap/Spd)	43.4%	29.0%	26.3%	25.5%	40.4%	27.5%
Count: 40,000 to 50,000						
# Links	0	7	64	30	4	105
Avg Count		43,815.6	43,871.1	44,327.7	41,991.3	43,926.3
Joint (D-FW Cap/Spd)		23.4%	26.7%	21.9%	15.2%	25.9%
Texas (D-FW Cap/Spd)		15.2%	28.9%	22.2%	18.2%	29.2%
Texas (H-G Cap/Spd)		16.0%	24.2%	21.6%	20.9%	23.9%
Count: 50,000 to 75,000						
# Links	1	22	76	20	1	120
Avg Count	62,212.0	61,504.1	61,234.6	56,831.1	51,000.0	60,472.9
Joint (D-FW Cap/Spd)		20.2%	20.0%	13.3%		20.2%
Texas (D-FW Cap/Spd)		19.4%	20.2%	11.7%		20.4%
Texas (H-G Cap/Spd)		21.3%	19.0%	14.7%		21.5%
Count: 75,000 to 100,000						
# Links	0	6	11	0	0	17
Avg Count		92,520.3	80,959.9			85,040.1
Joint (D-FW Cap/Spd)		7.3%	12.8%			10.9%
Texas (D-FW Cap/Spd)		10.8%	9.0%			9.7%
Texas (H-G Cap/Spd)		9.6%	13.3%			11.6%
Count: 100,000 and above						
# Links	0	5	10	3	0	18
Avg Count		113,057.4	109,376.3	107,067.0		110,013.9
Joint (D-FW Cap/Spd)		4.8%	5.0%	3.1%		7.0%
Texas (D-FW Cap/Spd)		8.6%	5.0%	1.4%		7.5%
Texas (H-G Cap/Spd)		12.0%	4.2%	1.3%		7.1%
ALL COUNTED LINKS						
# Links	236	295	1,739	1,448	1,148	4,866
Avg Count	8,954.4	23,433.8	19,547.7	12,778.1	5,615.4	13,968.1
Joint (D-FW Cap/Spd)	89.7%	36.0%	44.1%	52.0%	67.6%	51.4%
Texas (D-FW Cap/Spd)	64.4%	39.7%	40.2%	53.3%	71.1%	50.0%
Texas (H-G Cap/Spd)	84.5%	46.7%	42.1%	46.9%	64.6%	50.3%

Table 29
Percent Standard Deviation by Volume Group and Area Type for Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Count: Under 5,000						
# Links	0	0	25	92	74	191
Avg Count			2,972.2	2,699.7	1,744.5	2,365.3
Joint (D-FW Cap/Spd)			155.0%	83.5%	134.1%	119.0%
Texas (D-FW Cap/Spd)			131.8%	83.4%	171.1%	120.6%
Texas (H-G Cap/Spd)			143.3%	112.5%	111.8%	121.1%
Count: 5,000 to 10,000						
# Links	0	0	34	38	16	88
Avg Count			7,260.8	6,859.3	7,774.2	7,180.8
Joint (D-FW Cap/Spd)			67.4%	50.5%	50.8%	57.6%
Texas (D-FW Cap/Spd)			54.8%	40.9%	54.4%	49.8%
Texas (H-G Cap/Spd)			61.7%	74.4%	65.4%	67.2%
Count: 10,000 to 20,000						
# Links	0	0	64	45	20	129
Avg Count			15,216.0	14,348.5	15,813.1	15,005.9
Joint (D-FW Cap/Spd)			54.2%	38.3%	15.9%	45.9%
Texas (D-FW Cap/Spd)			52.8%	34.5%	21.2%	44.1%
Texas (H-G Cap/Spd)			41.9%	30.1%	22.0%	36.9%
Count: 20,000 to 30,000						
# Links	0	0	39	13	7	59
Avg Count			24,525.9	23,591.8	21,947.9	24,014.3
Joint (D-FW Cap/Spd)			41.9%	33.3%	10.8%	37.9%
Texas (D-FW Cap/Spd)			30.3%	30.0%	16.8%	28.9%
Texas (H-G Cap/Spd)			28.1%	29.3%	19.7%	27.9%
Count: 30,000 to 40,000						
# Links	0	0	29	5	0	34
Avg Count			33,175.8	34,097.2		33,311.3
Joint (D-FW Cap/Spd)			28.6%	26.5%		28.0%
Texas (D-FW Cap/Spd)			27.3%	10.0%		27.2%
Texas (H-G Cap/Spd)			24.0%	16.6%		22.8%
Count: 40,000 to 50,000						
# Links	0	0	6	2	0	8
Avg Count			41,229.3	43,948.5		41,909.1
Joint (D-FW Cap/Spd)			9.5%	.9%		16.0%
Texas (D-FW Cap/Spd)			4.4%	.3%		5.9%
Texas (H-G Cap/Spd)			9.2%	5.8%		17.7%
Count: 50,000 to 75,000						
# Links	0	0	8	2	0	10
Avg Count			67,274.3	51,385.5		64,096.5
Joint (D-FW Cap/Spd)			6.4%	6.1%		7.3%
Texas (D-FW Cap/Spd)			6.5%	.4%		6.2%
Texas (H-G Cap/Spd)			10.1%	6.6%		9.6%
Count: 75,000 to 100,000						
# Links	0	0	2	0	0	2
Avg Count			78,746.0			78,746.0
Joint (D-FW Cap/Spd)			1.7%			1.7%
Texas (D-FW Cap/Spd)			2.0%			2.0%
Texas (H-G Cap/Spd)			.4%			.4%
Count: 100,000 and above						
# Links	0	0	0	0	0	0
ALL COUNTED LINKS						
# Links	0	0	207	197	117	521
Avg Count			20,080.5	9,251.5	6,182.7	12,864.9
Joint (D-FW Cap/Spd)			39.4%	45.8%	43.8%	45.4%
Texas (D-FW Cap/Spd)			35.5%	41.7%	57.0%	41.7%
Texas (H-G Cap/Spd)			33.4%	49.2%	52.8%	41.2%

Table 30
Percent Standard Deviation by Functional Class and Area Type for Regional Networks

	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	3	39	179	216	136	573
Avg Count	31,710.7	63,632.9	51,814.7	31,714.0	16,265.2	36,499.0
Joint (D-FW Cap/Spd)	21.9%	15.1%	18.9%	23.4%	28.2%	21.9%
Texas (D-FW Cap/Spd)	4.6%	21.5%	18.6%	24.5%	32.5%	23.2%
Texas (H-G Cap/Spd)	107.2%	20.6%	21.7%	25.0%	26.6%	27.2%
Principal Arterials						
# Links	60	72	365	171	73	741
Avg Count	14,285.6	26,683.1	26,061.5	19,494.2	15,872.2	22,649.1
Joint (D-FW Cap/Spd)	56.7%	33.2%	36.7%	39.2%	35.8%	38.7%
Texas (D-FW Cap/Spd)	44.7%	36.8%	32.5%	35.2%	34.7%	35.2%
Texas (H-G Cap/Spd)	39.5%	50.6%	37.6%	34.9%	35.8%	40.0%
Minor Arterials						
# Links	115	117	652	488	229	1,601
Avg Count	7,647.9	16,074.0	17,130.3	11,783.6	6,042.7	13,156.3
Joint (D-FW Cap/Spd)	103.3%	49.7%	52.4%	64.8%	69.9%	60.7%
Texas (D-FW Cap/Spd)	68.8%	43.2%	42.6%	58.4%	63.8%	52.1%
Texas (H-G Cap/Spd)	85.8%	53.8%	47.7%	54.3%	68.6%	54.9%
Collectors						
# Links	49	45	437	433	619	1,583
Avg Count	4,041.4	8,548.3	7,809.8	4,827.4	2,449.4	4,802.3
Joint (D-FW Cap/Spd)	78.3%	63.8%	83.4%	90.5%	111.1%	97.3%
Texas (D-FW Cap/Spd)	57.7%	62.0%	68.6%	83.0%	95.4%	85.1%
Texas (H-G Cap/Spd)	78.5%	75.1%	66.4%	84.3%	92.9%	87.3%
Locals						
# Links	0	0	0	0	0	0
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	9	22	106	140	91	368
Avg Count	9,270.8	11,125.5	5,889.1	3,415.9	1,931.9	4,365.4
Joint (D-FW Cap/Spd)	35.3%	92.7%	106.1%	129.3%	165.7%	120.9%
Texas (D-FW Cap/Spd)	36.9%	68.8%	96.1%	109.9%	146.1%	104.0%
Texas (H-G Cap/Spd)	46.0%	63.1%	86.1%	103.6%	156.3%	100.1%
TOTALS						
# Links	236	295	1,739	1,448	1,148	4,866
Avg Count	8,954.4	23,433.8	19,547.7	12,778.1	5,615.4	13,968.1
Joint (D-FW Cap/Spd)	89.7%	36.0%	44.1%	52.0%	67.6%	51.4%
Texas (D-FW Cap/Spd)	64.4%	39.7%	40.2%	53.3%	71.1%	50.0%
Texas (H-G Cap/Spd)	84.5%	46.7%	42.1%	46.9%	64.6%	50.3%

Note: CBD, Fringe, Urban Residential, Suburban Residential and Rural are printed under the spanning heading "Area Types".

Table 31
Percent Standard Deviation by Functional Class and Area Type for Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	0	0	22	19	12	53
Avg Count			50,877.5	30,335.8	18,783.9	36,247.0
Joint (D-FW Cap/Spd)			9.5%	23.6%	10.1%	16.4%
Texas (D-FW Cap/Spd)			7.2%	15.2%	20.3%	14.4%
Texas (H-G Cap/Spd)			18.6%	19.6%	14.2%	19.7%
Principal Arterials						
# Links	0	0	43	16	6	65
Avg Count			26,049.7	14,746.3	15,478.7	22,291.5
Joint (D-FW Cap/Spd)			37.3%	36.1%	24.2%	39.2%
Texas (D-FW Cap/Spd)			32.2%	32.0%	18.1%	32.8%
Texas (H-G Cap/Spd)			29.9%	35.9%	20.5%	31.5%
Minor Arterials						
# Links	0	0	106	80	26	212
Avg Count			16,451.7	9,196.5	8,031.5	12,681.2
Joint (D-FW Cap/Spd)			47.8%	49.3%	35.2%	49.5%
Texas (D-FW Cap/Spd)			42.6%	44.0%	42.6%	44.7%
Texas (H-G Cap/Spd)			36.8%	50.4%	47.8%	41.9%
Collectors & Locals						
# Links	0	0	24	67	63	154
Avg Count			4,844.8	3,524.1	2,905.5	3,476.9
Joint (D-FW Cap/Spd)			91.3%	65.1%	96.6%	84.6%
Texas (D-FW Cap/Spd)			80.8%	65.1%	124.3%	91.5%
Texas (H-G Cap/Spd)			66.9%	59.1%	95.7%	76.3%
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	0	0	12	15	10	37
Avg Count			4,755.8	2,560.0	1,323.2	2,937.9
Joint (D-FW Cap/Spd)			122.0%	107.8%	135.2%	141.9%
Texas (D-FW Cap/Spd)			109.3%	103.0%	191.0%	125.2%
Texas (H-G Cap/Spd)			82.0%	83.6%	209.7%	104.3%
TOTALS						
# Links	0	0	207	197	117	521
Avg Count			20,080.5	9,251.5	6,182.7	12,864.9
Joint (D-FW Cap/Spd)			39.4%	45.8%	43.8%	45.4%
Texas (D-FW Cap/Spd)			35.5%	41.7%	57.0%	41.7%
Texas (H-G Cap/Spd)			33.4%	49.2%	52.8%	41.2%

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 volumes. Tables 32 and 33 summarize the percent RMSE for the links stratified by volume group and area type in the two networks. Tables 34 and 35 display the percent RMSE results for the links stratified by functional class and area type.

- Again, as expected, links with the higher volumes and the links in functional classes which tend to carry the higher volumes tended to have the lower percent RMSE results.
- As with the percent standard deviation results, the percent RMSE results were surprisingly consistent for all three models.

Table 32
Percent RMSE by Volume Group and Area Type for Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Count: Under 5,000						
# Links	74	21	232	496	742	1,565
Avg Count	3,191.4	3,655.5	2,956.6	2,472.8	1,745.4	2,249.5
Joint (D-FW Cap/Spd)	116.7%	124.6%	128.1%	144.5%	123.4%	135.4%
Texas (D-FW Cap/Spd)	91.4%	105.1%	130.1%	132.1%	116.1%	126.5%
Texas (H-G Cap/Spd)	135.4%	124.1%	120.2%	132.9%	119.6%	129.5%
Count: 5,000 to 10,000						
# Links	83	65	339	280	196	963
Avg Count	7,483.3	7,350.1	7,391.8	7,082.0	7,080.3	7,243.4
Joint (D-FW Cap/Spd)	91.7%	67.0%	90.2%	80.7%	68.2%	82.2%
Texas (D-FW Cap/Spd)	69.5%	66.4%	77.2%	71.4%	63.5%	71.5%
Texas (H-G Cap/Spd)	75.4%	94.8%	86.3%	75.3%	64.5%	79.0%
Count: 10,000 to 20,000						
# Links	65	95	529	365	151	1,205
Avg Count	13,741.9	14,828.6	14,950.1	14,645.8	14,124.6	14,679.7
Joint (D-FW Cap/Spd)	77.6%	64.1%	57.8%	53.5%	37.0%	56.1%
Texas (D-FW Cap/Spd)	58.4%	61.9%	55.5%	52.3%	38.0%	53.4%
Texas (H-G Cap/Spd)	61.0%	62.4%	52.6%	46.2%	35.0%	50.3%
Count: 20,000 to 30,000						
# Links	11	44	292	160	42	549
Avg Count	21,754.0	24,668.1	24,605.8	24,349.8	24,180.3	24,446.5
Joint (D-FW Cap/Spd)	71.2%	38.1%	43.6%	37.5%	28.9%	41.0%
Texas (D-FW Cap/Spd)	60.8%	54.9%	42.8%	45.2%	34.9%	44.2%
Texas (H-G Cap/Spd)	63.6%	50.2%	41.9%	35.5%	27.1%	40.2%
Count: 30,000 to 40,000						
# Links	2	30	186	94	12	324
Avg Count	30,615.5	36,137.1	33,667.9	34,721.4	33,026.2	34,159.6
Joint (D-FW Cap/Spd)	112.9%	31.8%	34.1%	29.1%	37.7%	32.8%
Texas (D-FW Cap/Spd)	67.4%	34.6%	35.8%	33.4%	51.5%	35.5%
Texas (H-G Cap/Spd)	62.2%	33.7%	31.8%	27.6%	42.1%	31.1%
Count: 40,000 to 50,000						
# Links	0	7	64	30	4	105
Avg Count		43,815.6	43,871.1	44,327.7	41,991.3	43,926.3
Joint (D-FW Cap/Spd)		28.1%	27.2%	22.8%	35.8%	25.9%
Texas (D-FW Cap/Spd)		34.2%	31.0%	25.5%	37.9%	29.5%
Texas (H-G Cap/Spd)		21.6%	30.6%	21.9%	22.0%	27.2%
Count: 50,000 to 75,000						
# Links	1	22	76	20	1	120
Avg Count	62,212.0	61,504.1	61,234.6	56,831.1	51,000.0	60,472.9
Joint (D-FW Cap/Spd)		22.2%	20.2%	17.1%		20.2%
Texas (D-FW Cap/Spd)		25.3%	20.5%	15.7%		20.7%
Texas (H-G Cap/Spd)		35.8%	22.6%	15.0%		25.8%
Count: 75,000 to 100,000						
# Links	0	6	11	0	0	17
Avg Count		92,520.3	80,959.9			85,040.1
Joint (D-FW Cap/Spd)		15.3%	15.7%			15.0%
Texas (D-FW Cap/Spd)		15.8%	12.1%			13.2%
Texas (H-G Cap/Spd)		13.6%	16.6%			15.0%
Count: 100,000 and above						
# Links	0	5	10	3	0	18
Avg Count		113,057.4	109,376.3	107,067.0		110,013.9
Joint (D-FW Cap/Spd)		6.2%	9.9%	3.2%		7.9%
Texas (D-FW Cap/Spd)		12.8%	5.6%	2.1%		7.6%
Texas (H-G Cap/Spd)		21.7%	23.3%	22.8%		21.4%
ALL COUNTED LINKS						
# Links	236	295	1,739	1,448	1,148	4,866
Avg Count	8,954.4	23,433.8	19,547.7	12,778.1	5,615.4	13,968.1
Joint (D-FW Cap/Spd)	93.1%	38.6%	45.7%	52.6%	67.6%	52.4%
Texas (D-FW Cap/Spd)	69.8%	43.5%	45.0%	54.7%	71.2%	52.7%
Texas (H-G Cap/Spd)	85.9%	47.5%	45.0%	48.5%	64.6%	51.9%

Table 33
Percent RMSE by Volume Group and Area Type for Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Count: Under 5,000						
# Links	0	0	25	92	74	191
Avg Count			2,972.2	2,699.7	1,744.5	2,365.3
Joint (D-FW Cap/Spd)			176.3%	83.6%	139.2%	120.9%
Texas (D-FW Cap/Spd)			145.6%	83.5%	179.6%	123.8%
Texas (H-G Cap/Spd)			144.4%	114.3%	124.2%	124.6%
Count: 5,000 to 10,000						
# Links	0	0	34	38	16	88
Avg Count			7,260.8	6,859.3	7,774.2	7,180.8
Joint (D-FW Cap/Spd)			67.5%	50.9%	52.0%	57.6%
Texas (D-FW Cap/Spd)			55.3%	42.1%	54.8%	49.8%
Texas (H-G Cap/Spd)			64.9%	77.7%	65.9%	69.7%
Count: 10,000 to 20,000						
# Links	0	0	64	45	20	129
Avg Count			15,216.0	14,348.5	15,813.1	15,005.9
Joint (D-FW Cap/Spd)			56.0%	39.2%	17.1%	46.0%
Texas (D-FW Cap/Spd)			53.1%	36.0%	27.7%	44.3%
Texas (H-G Cap/Spd)			43.8%	30.4%	27.9%	37.3%
Count: 20,000 to 30,000						
# Links	0	0	39	13	7	59
Avg Count			24,525.9	23,591.8	21,947.9	24,014.3
Joint (D-FW Cap/Spd)			41.9%	33.6%	11.0%	37.9%
Texas (D-FW Cap/Spd)			30.5%	30.7%	17.7%	29.2%
Texas (H-G Cap/Spd)			30.1%	29.4%	21.2%	28.8%
Count: 30,000 to 40,000						
# Links	0	0	29	5	0	34
Avg Count			33,175.8	34,097.2		33,311.3
Joint (D-FW Cap/Spd)			28.7%	28.7%		28.3%
Texas (D-FW Cap/Spd)			27.9%	26.2%		27.2%
Texas (H-G Cap/Spd)			24.3%	19.0%		23.3%
Count: 40,000 to 50,000						
# Links	0	0	6	2	0	8
Avg Count			41,229.3	43,948.5		41,909.1
Joint (D-FW Cap/Spd)			18.0%	22.2%		17.3%
Texas (D-FW Cap/Spd)			17.3%	6.6%		14.6%
Texas (H-G Cap/Spd)			11.9%	37.2%		17.8%
Count: 50,000 to 75,000						
# Links	0	0	8	2	0	10
Avg Count			67,274.3	51,385.5		64,096.5
Joint (D-FW Cap/Spd)			7.5%	11.2%		7.5%
Texas (D-FW Cap/Spd)			11.8%	10.7%		11.3%
Texas (H-G Cap/Spd)			20.0%	34.9%		20.7%
Count: 75,000 to 100,000						
# Links	0	0	2	0	0	2
Avg Count			78,746.0			78,746.0
Joint (D-FW Cap/Spd)			23.8%			23.8%
Texas (D-FW Cap/Spd)			20.6%			20.6%
Texas (H-G Cap/Spd)			16.3%			16.3%
Count: 100,000 and above						
# Links	0	0	0	0	0	0
ALL COUNTED LINKS						
# Links	0	0	207	197	117	521
Avg Count			20,080.5	9,251.5	6,182.7	12,864.9
Joint (D-FW Cap/Spd)			40.2%	46.1%	43.8%	45.5%
Texas (D-FW Cap/Spd)			35.7%	41.8%	57.1%	41.7%
Texas (H-G Cap/Spd)			33.7%	49.4%	52.8%	41.4%

Table 34
Percent RMSE by Functional Class and Area Type for Regional Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	3	39	179	216	136	573
Avg Count	31,710.7	63,632.9	51,814.7	31,714.0	16,265.2	36,499.0
Joint (D-FW Cap/Spd)	69.2%	15.1%	19.1%	24.4%	34.7%	22.6%
Texas (D-FW Cap/Spd)	37.1%	22.4%	19.8%	30.2%	46.1%	26.7%
Texas (H-G Cap/Spd)	125.7%	26.0%	23.6%	25.0%	33.1%	27.5%
Principal Arterials						
# Links	60	72	365	171	73	741
Avg Count	14,285.6	26,683.1	26,061.5	19,494.2	15,872.2	22,649.1
Joint (D-FW Cap/Spd)	77.4%	38.2%	38.2%	40.7%	36.5%	41.0%
Texas (D-FW Cap/Spd)	63.6%	45.2%	39.8%	40.9%	37.2%	42.2%
Texas (H-G Cap/Spd)	60.7%	51.1%	40.2%	39.2%	40.1%	43.0%
Minor Arterials						
# Links	115	117	652	488	229	1,601
Avg Count	7,647.9	16,074.0	17,130.3	11,783.6	6,042.7	13,156.3
Joint (D-FW Cap/Spd)	103.4%	55.2%	55.9%	66.8%	70.1%	63.1%
Texas (D-FW Cap/Spd)	69.2%	55.4%	53.6%	66.0%	66.2%	60.2%
Texas (H-G Cap/Spd)	89.6%	54.7%	48.8%	55.0%	68.8%	55.1%
Collectors						
# Links	49	45	437	433	619	1,583
Avg Count	4,041.4	8,548.3	7,809.8	4,827.4	2,449.4	4,802.3
Joint (D-FW Cap/Spd)	94.4%	74.6%	89.2%	92.4%	112.1%	100.6%
Texas (D-FW Cap/Spd)	77.1%	74.2%	82.4%	91.7%	100.3%	94.4%
Texas (H-G Cap/Spd)	83.6%	84.2%	86.0%	99.1%	97.1%	99.2%
Locals						
# Links	0	0	0	0	0	0
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	9	22	106	140	91	368
Avg Count	9,270.8	11,125.5	5,889.1	3,415.9	1,931.9	4,365.4
Joint (D-FW Cap/Spd)	71.5%	93.3%	107.3%	136.8%	178.8%	124.9%
Texas (D-FW Cap/Spd)	74.0%	74.7%	99.7%	119.8%	159.1%	111.0%
Texas (H-G Cap/Spd)	75.7%	77.7%	91.2%	106.5%	157.3%	104.7%
TOTALS						
# Links	236	295	1,739	1,448	1,148	4,866
Avg Count	8,954.4	23,433.8	19,547.7	12,778.1	5,615.4	13,968.1
Joint (D-FW Cap/Spd)	93.1%	38.6%	45.7%	52.6%	67.6%	52.4%
Texas (D-FW Cap/Spd)	69.8%	43.5%	45.0%	54.7%	71.2%	52.7%
Texas (H-G Cap/Spd)	85.9%	47.5%	45.0%	48.5%	64.6%	51.9%

Table 35
Percent RMSE by Functional Class and Area Type for Subarea Networks

	Area Types					
	CBD	Fringe	Urban Residential	Suburban Residential	Rural	TOTALS
Freeways						
# Links	0	0	22	19	12	53
Avg Count			50,877.5	30,335.8	18,783.9	36,247.0
Joint (D-FW Cap/Spd)			15.2%	24.1%	10.5%	18.2%
Texas (D-FW Cap/Spd)			17.4%	21.1%	20.9%	19.4%
Texas (H-G Cap/Spd)			19.1%	22.5%	14.5%	20.7%
Principal Arterials						
# Links	0	0	43	16	6	65
Avg Count			26,049.7	14,746.3	15,478.7	22,291.5
Joint (D-FW Cap/Spd)			40.8%	37.3%	25.0%	40.7%
Texas (D-FW Cap/Spd)			32.6%	32.2%	26.9%	32.9%
Texas (H-G Cap/Spd)			30.6%	36.8%	31.7%	31.8%
Minor Arterials						
# Links	0	0	106	80	26	212
Avg Count			16,451.7	9,196.5	8,031.5	12,681.2
Joint (D-FW Cap/Spd)			47.8%	49.6%	35.3%	49.5%
Texas (D-FW Cap/Spd)			42.9%	45.4%	42.7%	45.1%
Texas (H-G Cap/Spd)			38.6%	58.9%	53.0%	45.4%
Collectors & Locals						
# Links	0	0	24	67	63	154
Avg Count			4,844.8	3,524.1	2,905.5	3,476.9
Joint (D-FW Cap/Spd)			92.0%	67.5%	97.6%	84.7%
Texas (D-FW Cap/Spd)			80.9%	66.3%	126.3%	91.5%
Texas (H-G Cap/Spd)			80.4%	71.8%	96.3%	82.4%
Ramps						
# Links	0	0	0	0	0	0
Frontage Roads						
# Links	0	0	12	15	10	37
Avg Count			4,755.8	2,560.0	1,323.2	2,937.9
Joint (D-FW Cap/Spd)			134.7%	123.7%	145.5%	141.9%
Texas (D-FW Cap/Spd)			112.3%	112.4%	192.1%	125.3%
Texas (H-G Cap/Spd)			84.3%	84.6%	246.0%	104.3%
TOTALS						
# Links	0	0	207	197	117	521
Avg Count			20,080.5	9,251.5	6,182.7	12,864.9
Joint (D-FW Cap/Spd)			40.2%	46.1%	43.8%	45.5%
Texas (D-FW Cap/Spd)			35.7%	41.8%	57.1%	41.7%
Texas (H-G Cap/Spd)			33.7%	49.4%	52.8%	41.4%

VII. FINDINGS, OBSERVATIONS AND RECOMMENDATIONS

As noted at the outset, the comparative analysis of the Texas Model and the Joint Model Capacity Restraint Procedure was undertaken to identify how the results from these two procedures differ relative to their comparison to counts. If the models were found to significantly differ in their ability to replicate the observed counts, the analyses would attempt to identify the procedural differences in the models which accounted for most of the difference in the assignment results. In other words, the basic goal of these analyses was to attempt to objectively compare the two procedures, evaluate how the results of the two procedures differ, and identify (if possible) the primary sources of any differences that may be observed in their ability to replicate observed volumes. It was anticipated that these comparisons would provide the basis for recommending improvements to one or both procedures.

The following paragraphs highlight some of the more interesting findings and observations from the comparative analyses and also highlight the recommended changes or improvements in the current procedures or models:

- **Ability to Replicate Counts:** One of the basic criteria used in judging the adequacy of an assignment model is its ability to replicate observed travel behavior reflected in available count data. When the two model results were compared to available count data, neither model emerged as clearly superior. Indeed, the percent standard deviation and the percent RMSE reflected similar levels of accuracy (relative to available counts) for both models. In view of the major structural differences in the two models, both provided surprisingly comparable results relative to the available count data.
- **Minimum Time versus Minimum Cost Paths:** Neither the use of minimum time paths (as in the Texas Model) nor the use of minimum cost paths (as in the Joint Model) emerged as the preferred approach. The use of minimum cost paths requires developing and forecasting additional data (i.e., the average vehicle operating cost per mile, the average value of time, and toll costs). The minimum cost path approach may offer some salient advantages in dealing with highway networks containing toll facilities. It is recommended,

therefore, that the option of using minimum cost paths be provided as an option in the Texas Package.

- **Importance of Input Link Speeds and Capacities:** The capacity restraint assignment results appeared to be more sensitive to the basic network parameters of speed and capacity than the model selected for application. It appears that the input link speeds (particularly the relative differences in the freeway and non-freeway speeds within a given area type) probably have more impact on the capacity restraint assignment results than the capacity estimates. This suggests that the initial model calibration efforts should probably focus more on input speed refinements using simple all-or-nothing assignments. It appeared that both the Texas Model and the Joint Model would benefit from improvements in the input speed estimates.
- **Use of Directional Hourly versus Nondirectional 24-hour Capacities:** Regardless of which approach is used, the expected K-factor (i.e., the expected ratio of the peak-hour volume to the 24-hour volume) is used. In the Joint Model, the K-factor is essentially used to factor the 24-hour assignment volume to an estimated peak-hour. In developing the 24-hour capacity estimates for input to the Texas Model, the K-factor is applied to the hourly capacity to develop the 24-hour capacity estimate. Both are equivalent approaches while (as discussed in Chapter III) there is a difference in the directional and nondirectional K-factors. Perhaps the key difference is that the Joint Model allows the input of only two K-factors for a given assignment application (i.e., the K-factor for high capacity facilities and the K-factor for low capacity facilities). Consideration might be given to providing the analyst the option of specifying the K-factors stratified by the six facility types and the five area types (i.e., the specification of 30 K-factors rather than just two). This option would offer much of the flexibility intrinsic to the Texas Model approach.

It should be noted that the nondirectional nature of 24-hour volumes (i.e., the general tendency of 24-hour counts on two-way facilities to be approximately equal in each direction) eliminates most of the perceived value of factoring to a peak-hour volume. It would appear that implicit to the Joint Model approach is an underlying assumption that the typical directional split for the peak-hour is 50-50. In contrast, the Texas Model allows the consideration of typical peak-hour directional splits in computing nondirectional 24-hour capacities.

Structurally, it appears that the Joint Model was probably initially developed to deal with peak-hour trip tables and produce peak-hour assignments. It was probably adapted to perform 24-hour assignments using 24-hour trip tables by adding the two input K-factors. The Texas Model used in this study (i.e., the capacity restraint model in the ASSIGN SELF-BALANCING routine) was designed for 24-hour assignments as reflected in its use of nondirectional 24-hour speeds, nondirectional 24-hour capacities, and nondirectional V/C ratios in its impedance adjustment function. Indeed, a new routine was recently added to the Texas software (i.e., the PEAK CAPACITY RESTRAINT routine) to provide for time-of-day assignments rather than 24-hour assignments.

- Travel Time/Speed Adjustments: The two models differ significantly in their travel time/speed adjustments. The Texas Model employs an impedance adjustment function which is similar to the traditional BPR function. Using the V/C ratio for a link, the function is applied to compute the factor to be applied to the link's initial travel time. In contrast the Joint Model employs two delay equations (one for high capacity facilities such as freeways and one for low capacity facilities such as arterials). Using the V/C ratio for a link, the appropriate delay equation is applied to compute the estimated delay on the link which is added to the link's estimated travel time based on its input speed. While the graphical comparison indicated that the Joint Model travel time/speed adjustments are much larger than the Texas Model's, the difference did not produce significantly different assignment results. The Joint Model's use of link travel cost (i.e., essentially a weighting of a link's travel time and distance) rather than travel time probably reduced the impact of the differences in the adjustments.

The Texas Model software was judged to be somewhat rigid and inflexible in that it employs the same impedance adjustment function for all facility types and all urban areas (large or small with congested or relatively uncongested networks). The Joint Model provided some flexibility in this regard since it allows the user to specify the coefficients of the two delay equations (i.e., essentially equations for freeways and for non-freeway facilities). During the model calibration/validation process, these coefficients can be adjusted to better replicate observed travel behavior in the available count data.

The flexibility of using different travel time/speed adjustments for different urban areas and different facility types is probably less important when dealing with extremely congested networks (like the Dallas-Fort Worth applications) than for relatively uncongested networks associated with smaller urban areas. To correct for this limitation, the D-10 analysts have sometimes found it necessary to input LOS A or B capacity to get the desired path diversion. While this works, the use of such capacities makes the subsequent analyses more difficult. Rather than adjusting the capacities to achieve the desired assignment results, it would seem to be more desirable to use different travel time/speed adjustment functions to achieve essentially the same results.

The Joint Model is more flexible in this regard in that it allows the user to input the coefficients for the freeway delay model and the arterial delay model. The TRANPLAN micro-computer software adopted by the TxDOT for subarea analyses provides the user the option of specifying different speed adjustment functions for each facility type (i.e., a still more flexible approach than the Joint Model approach). It is recommended that the Texas Model software be updated to provide the user the option of specifying different travel time/speed adjustments by functional classification code.

- <u>Iterative versus Incremental Techniques:</u> As noted at the outset, the Texas Model is an iterative capacity restraint model while the Joint Model is incremental capacity restraint model. This is a fundamental difference in the models. As previously discussed, when the two model results were compared to available count data, neither model emerged as clearly superior. In view of the major structural differences in incremental versus iterative models, both provided surprisingly comparable results relative to the available count data.
- <u>Equilibrium Perspective</u>: An equilibrium capacity restraint assignment model is basically an iterative assignment model where the iteration weights are computed using an optimization function. The Texas Model is not an equilibrium assignment technique because it requires the user

to input the iteration weights. Because the Joint Model is an incremental capacity restraint assignment model (rather than an iterative model) it is not an equilibrium model.

While never implemented as an option in the Texas Model software, the equilibrium capacity restraint models have become a widely used procedure in operational studies in the past 10 years. It is the capacity restraint procedure which the United States Department of Transportation (U.S.DOT) generally encourages. The use of equilibrium assignments is also specified in the Environmental Protection Agency (EPA) reports entitled "Quality Review Guidelines for Base Year Emission Inventories" (September 1991) and "Section 187 VMT Forecasting and Tracking Guidance" (January 1992). It is expected that future EPA documents will cite Equilibrium Capacity Restraint Assignment procedures as the preferred (and perhaps the required) assignment model for use in developing mobile source emission estimates.

The principle difference between an equilibrium capacity restraint assignment model and the current Texas Model is that the model would compute the iteration weights. It is recommended that an equilibrium procedure be implemented as an option in the Texas Model. As previously noted, this option cannot be implemented in the Joint Model since it is an incremental assignment technique. It is possible that future EPA requirements will necessitate the adoption of a different assignment model for the Dallas-Fort Worth region.

In summary, the comparative analyses suggest that both models reasonably replicated observed counts and neither model emerged as clearly superior. Recognizing the evolving emphasis on equilibrium techniques and that such techniques cannot be implemented in an incremental model (such as the Joint Model), it is recommended that the Texas Model (both the ASSIGN SELF-BALANCING routine and the PEAK CAPACITY RESTRAINT routine) be updated to provide an equilibrium option. It is further recommended that two new options be provided in the Texas Model software -- the option of using minimum cost paths using a link cost formulation (similar to the option in the Joint Model) and the option of introducing user-specified travel time/speed adjustment functions by functional classification (preferably more like the option provided in the TRANPLAN software than the option provided in the Joint Model).

REFERENCES

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2. Development, Update and Calibration of the 1985 Travel Demand Models for the Houston-Galveston Region. Prepared by: Houston-Galveston Area Council and Texas Transportation Institute, June 1991.

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APPENDIX A

Capacities and Speeds Used in Houston-Galveston 24-Hour Networks

Capacity and speed look-up tables are used in developing networks for the Houston-Galveston region. Table A-1 summarizes the look-up table for the 24-hour nondirectional highway capacities used in the Houston-Galveston region's highway networks. Similarly, Table A-2 summarizes the look-up table for the 24-hour network speeds.

The methods used to estimate the 24-hour nondirectional capacities are discussed in Chapter III of this report. The Dallas-Fort Worth networks used in this study use a somewhat different stratification of links by type and area. Appendix B presents the adaptation of the Houston-Galveston capacity and speed look-up tables for application to the Dallas-Fort Worth networks used in this study.

Table A-1
Houston-Galveston 24-Hour Capacity Look-up Table

Facility Type	Lanes	CBD	Urban	Inner Suburban	Suburban	Rural
		Area Types				
Radial Freeways (without frontage roads)	4	89,000	100,500	89,500	67,500	49,000
	6	133,500	150,500	134,500	101,000	74,000
	8	178,000	201,000	179,000	135,000	98,500
	10	222,500	251,000	224,000	168,500	123,000
	12	267,000	301,000	269,000		
	14	311,500	351,500	313,500		
	16	356,000	401,500	358,500		
Radial Freeways (with frontage roads)	4	103,500	117,500	105,500	82,500	60,000
	6	148,000	167,500	150,500	116,000	85,000
	8	192,500	218,000	195,000	150,000	109,500
	10	237,000	268,000	240,000	183,500	134,000
	12	281,500	318,000	285,000		
	14	326,000	368,500	329,500		
	16	370,500	418,500	374,500		
Circumferential Freeways (without frontage roads)	4	84,500	95,500	89,000	73,500	53,000
	6	119,500	143,000	133,500	110,500	79,000
	8	159,500	190,500	178,000	147,000	105,500
	10	199,000	238,500	222,500	184,000	132,000
	12	239,000	286,000	267,000		
	14	278,500	334,000	311,500		
	16	318,500	381,500	356,000		
Circumferential Freeways (with frontage roads)	4	99,000	112,500	105,000	88,500	64,000
	6	134,000	160,000	149,500	125,500	90,000
	8	174,000	207,500	194,000	162,000	116,500
	10	213,500	255,500	238,500	199,000	143,000
	12	253,500	303,000	283,000		
	14	293,000	351,000	327,500		
	16	333,000	398,500	372,000		
Principal Arterials (with some grade separations)	4	37,900	44,400	43,500	40,300	33,700
	6	55,300	64,800	63,500	58,800	49,100
	8	73,800	86,400	84,600	78,400	65,500
Principal Arterials-Divided	4	29,300	32,600	31,500	27,800	22,700
	6	42,800	47,600	46,000	40,500	33,100
	8	57,000	63,500	61,300	54,100	44,100
Principal Arterials-Undivided	2	13,700	15,200	14,900	13,300	10,800
	4	26,300	29,300	28,700	25,600	20,900
	6	38,000	42,400	41,400	37,000	30,200
	8	50,100	55,900	54,600	48,700	39,800
Other Arterials-Divided	4	25,700	31,500	28,000	24,400	19,200
	6	37,600	45,900	40,900	35,600	28,000
	8	50,100	61,200	54,500	47,400	37,400
Other Arterials-Undivided	2	12,300	15,100	13,400	11,700	9,500
	4	23,700	29,000	25,800	22,500	18,300
	6	34,200	41,900	37,300	32,500	26,500
	8	45,100	55,200	49,200	42,800	34,900
One-way Pair (two-way links representing a pair of one-way streets)	4	29,400	34,200	32,700	28,500	23,700
	6	43,100	50,100	47,800	41,700	34,700
	8	56,000	65,200	62,200	54,300	45,100
	10	70,100	81,400	77,800	67,800	56,400
	12	84,100	97,700	93,300	81,400	67,700
	14	98,100	114,000	108,900	95,000	79,000
	16	112,100	130,300	124,400	108,500	90,300

Table A-1 (Continued)
Houston-Galveston 24-Hour Capacity Look-up Table

Facility Type	Lanes	Area Types: CBD	Urban	Inner Suburban	Suburban	Rural
One-way Arterials	2	14,700	17,100	16,300	14,200	11,800
	3	21,500	25,000	23,900	20,900	17,400
	4	28,000	32,600	31,100	27,100	22,600
	5	35,000	40,700	38,900	33,900	28,200
	6	42,000	48,900	46,700	40,700	33,900
	7	49,000	57,000	54,400	47,500	39,500
	8	56,100	65,200	62,200	54,300	45,100
Saturated Arterials	2	18,900	21,300	20,800	20,500	14,800
	4	37,600	42,300	41,500	40,700	29,400
	6	56,100	63,100	61,900	60,700	43,800
	8	74,400	83,700	82,100	80,600	58,200
Major Collectors	2	12,200	14,900	13,300	11,600	8,200
	4	23,400	28,700	25,600	22,200	15,700
	6	33,800	41,400	36,900	32,100	22,800
	8	44,600	54,500	48,600	42,300	30,000
Collectors	2	8,700	10,300	10,100	6,600	3,600
	4	16,200	19,100	18,700	12,300	6,700
	6	24,100	28,000	27,500	17,600	9,800
	8	33,900	39,400	38,700	24,300	13,200
Ferries	2	7,000	7,000	7,000	7,000	7,000
Saturated Arterials	2	18,900	21,300	20,800	20,500	14,800
	4	37,600	42,300	41,500	40,700	29,400
	6	56,100	63,100	61,900	60,700	43,800
	8	74,400	83,700	82,100	80,600	58,200
Radial Tollways (without frontage roads)	4	57,000	52,000	48,000	41,000	34,000
	6	86,000	78,000	71,000	61,000	51,000
	8	114,000	104,000	95,000	82,000	68,000
	10	143,000	130,000	119,000	102,000	84,000
	12	171,000	156,000	143,000		
	14	200,000	182,000	166,000		
	16	229,000	208,000	190,000		
Radial Tollways (with frontage roads)	4	71,500	69,000	64,000	56,000	45,000
	6	100,500	95,000	87,000	76,000	62,000
	8	128,500	121,000	111,000	97,000	79,000
	10	157,500	147,000	135,000	117,000	95,000
	12	185,500	173,000	159,000		
	14	214,500	199,000	182,000		
	16	243,500	225,000	206,000		
Circumferential Tollways (without frontage roads)	4	60,000	57,000	54,000	48,000	45,000
	6	90,000	85,000	81,000	73,000	67,000
	8	119,000	113,000	108,000	97,000	90,000
	10	149,000	142,000	135,000	121,000	112,000
	12	179,000	170,000	162,000		
	14	209,000	199,000	189,000		
	16	239,000	227,000	216,000		
Circumferential Tollways (with frontage roads)	4	74,500	74,000	70,000	63,000	56,000
	6	104,500	102,000	97,000	88,000	78,000
	8	133,500	130,000	124,000	112,000	101,000
	10	163,500	159,000	151,000	136,000	123,000
	12	193,500	187,000	178,000		
	14	223,500	216,000	205,000		
	16	253,500	244,000	232,000		

Table A-2
Houston-Galveston 24-Hour Capacity Look-up Table

Facility Type	CBD	Urban	Inner Suburban	Suburban	Rural
	Area Types				
Radial Freeway (without frontage roads)	40	45	50	55	60
Radial Freeway (with frontage roads)	40	45	50	55	60
Circum. Freeway (without frontage roads)	40	45	50	55	60
Circum. Freeway (with frontage roads)	40	45	50	55	60
Principal Arterial with Grade Separations	35	35	42	45	55
Principal Arterial - Divided	17	30	34	39	51
Principal Arterial - Undivided	17	30	34	38	50
Other Arterial - Divided	17	30	34	37	49
Other Arterial - Undivided	17	29	33	36	48
One-way Arterial Pairs	17	33	37	40	52
One-way Arterial Links	17	33	37	40	52
Saturated Arterials	17	30	34	39	51
Major Collectors	17	29	33	36	45
Collectors	15	24	25	26	36
Ferries	15	15	15	15	15
Radial Tollway (without frontage roads)	45	50	55	60	60
Radial Tollway (with frontage roads)	45	50	55	60	60
Circum. Tollway (without frontage roads)	45	50	55	60	60
Circum. Tollway (with frontage roads)	45	50	55	60	60

APPENDIX B

Houston-Galveston 24-Hour Capacities and Speeds Used in Dallas-Fort Worth Networks

As discussed in Appendix A, capacity and speed look-up tables are used to develop networks for the Houston-Galveston region. Since the capacities and speeds were developed for use with the Texas Model and are felt to be typical of the capacities and speeds used in most applications of the Texas Capacity Restraint Assignment Procedure, these tables were the basis for estimating a set of 24-hour capacities and speeds for use with the Dallas-Fort Worth networks in this study. Table B-1 summarizes the 24-hour nondirectional highway capacities estimated from the Houston-Galveston data for use in the Dallas-Fort Worth highway networks. Similarly, Table B-2 summarizes the 24-hour network speeds borrowed from the Houston-Galveston models for use with the Dallas-Fort Worth networks.

Table B-1
Houston-Galveston 24-hour Capacities Used Dallas-Fort Worth Networks

Facility Type	Lanes	Area Types: CBD	Fringe	Urban Residential	Suburban Residential	Rural
Freeways	4	89,000	100,500	89,500	67,500	49,000
	6	133,500	150,500	134,500	101,000	74,000
	8	178,000	201,000	179,000	135,000	98,500
	10	222,500	251,000	224,000	168,500	123,000
	12	267,000	301,000	269,000	202,200	147,600
	14	311,500	351,500	313,500	235,900	172,200
	16	356,000	401,500	358,500	269,600	196,800
Principal Arterials-Divided	4	29,300	32,600	31,500	27,800	22,700
	6	42,800	47,600	46,000	40,500	33,100
	8	57,000	63,500	61,300	54,100	44,100
Principal Arterials-Undivided	2	13,700	15,200	14,900	13,300	10,800
	4	26,300	29,300	28,700	25,600	20,900
	6	38,000	42,400	41,400	37,000	30,200
	8	50,100	55,900	54,600	48,700	39,800
Minor Arterials-Divided	4	25,700	31,500	28,000	24,400	19,200
	6	37,600	45,900	40,900	35,600	28,000
	8	50,100	61,200	54,500	47,400	37,400
Minor Arterials-Undivided	2	12,300	15,100	13,400	11,700	9,500
	4	23,700	29,000	25,800	22,500	18,300
	6	34,200	41,900	37,300	32,500	26,500
	8	45,100	55,200	49,200	42,800	34,900
Collectors-Divided	4	24,500	28,500	28,000	17,500	9,500
	6	34,000	39,500	39,000	24,500	13,500
	8	43,500	50,500	50,000	31,000	17,000
Collectors-Undivided	2	8,700	10,300	10,100	6,600	3,600
	4	16,200	19,100	18,700	12,300	6,700
	6	24,100	28,000	27,500	17,600	9,800
	8	33,900	39,400	38,700	24,300	13,200
Locals - Divided	4	24,500	28,500	28,000	17,500	9,500
	6	34,000	39,500	39,000	24,500	13,500
	8	43,500	50,500	50,000	31,000	17,000
Locals - Undivided	2	8,700	10,300	10,100	6,600	3,600
	4	16,200	19,100	18,700	12,300	6,700
	6	24,100	28,000	27,500	17,600	9,800
	8	33,900	39,400	38,700	24,300	13,200
Ramps (directional lanes & capacities)	1	13,200	16,200	14,400	12,500	9,900
	2	26,400	32,400	28,800	25,000	19,800
	3	38,900	47,700	42,400	36,900	29,100
	4	51,400	63,000	56,000	48,800	38,400
	6	75,200	91,800	81,800	71,200	56,000
Frontage Roads-Divided	2	13,200	16,200	14,400	12,500	9,900
	3	19,450	23,850	21,200	18,450	14,550
	4	25,700	31,500	28,000	24,400	19,200
Frontage Roads-Undivided	1	6,150	7,550	6,700	5,850	4,750
	2	12,300	15,100	13,400	11,700	9,500
	3	18,000	22,050	19,600	17,100	13,900
	4	23,700	29,000	25,800	22,500	18,300

Table B-2
Houston-Galveston 24-hour Speeds Used
Dallas-Fort Worth Networks

	Area Type				
Facility Type	CBD	Fringe	Urban Res.	Suburban Res.	Rural
Freeways	40	45	50	55	60
Principal Arterials - Divided	17	30	34	39	51
Principal Arterials - Undivided	17	30	34	38	50
Minor Arterials - Divided	17	30	34	37	49
Minor Arterials - Undivided	17	29	33	36	48
Collectors - Divided	17	29	33	36	45
Collectors - Undivided	15	24	25	26	36
Locals - Divided	17	29	33	36	45
Locals - Undivided	15	24	25	26	36
Ramps - Divided	17	30	34	37	49
Ramps - Undivided	17	29	33	36	48
Frontage Roads - Divided	17	30	34	37	49
Frontage Roads - Undivided	17	29	33	36	48