Appendix 3
Travel Model Validation

HOUSTON-GALVESTON AREA COUNCIL

REGIONAL TRAVEL MODELS

2002 Model Validation and Documentation Report

November 2006

1.0 Introduction

The Houston-Galveston Regional Travel Models are cooperatively developed and maintained by the Houston-Galveston Area Council (H-GAC), the Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority (METRO). This report documents the validation of the Houston-Galveston Regional "Track-1" Travel Models to the Base Year 2002. The Track-1 model set is an enhanced standard practice set of travel models that represent an update to the original H-GAC Travel Models – referred to as the "Track-0" model set. The Track-1 model set is essentially an update to the Track-0 model set based on 1995 travel survey data for the region. This report does not fully document the various model set components, but instead, documents those components that were addressed as part of the 2002 validation. The development of the "Track-0" model set is documented in the following reports.

- *Development, Update and Calibration of 1985 Travel Models for the Houston Galveston Region, H-GAC, June 1991*
- *Estimation, Calibration, and Validation of the Houston Mode Choice Model - Technical Report*
- 1990 Houston Long-Range Patronage Forecasting Model Validation-Draft Technical Memorandum: Model Validation Methodology and Results
- *IH-10 Katy Freeway Major Investment Study: Service and Travel Forecasting Methodology, Version 3.0*

The 'Track-1" Travel Models represent an update of the "Track-0" models using updated (relative to the original 1984 survey) household and work-place survey data. In terms of model structure, the only significant change to model set was the re-definition of trip purposes. The regional mode choice model is a nested logit model originally developed for incorporation into METRO's 1985 Houston Long-Range Patronage Forecasting Model based on 1985 travel survey information. The model was later enhanced for use in a Major Investment Study. The model has been re-calibrated to the year 1995 as part of the development of the Track-1 model set.

1.1 Report Structure

Chapter 2 of the report discusses the development of land use, demographic and cost data for the Base Year 2002. Included in this section is also a discussion and depiction of the zone system used in the H-GAC modeling efforts. Chapter 3 outlines the development of both highway and transit networks. This is followed in Chapter 4 with a discussion of travel forecasting procedures employed in the 1995 validation. The 2002 highway assignment validation results are also summarized in Chapter 4. Chapter 5 discusses the development of an HPMS adjustment factor used in applications of travel model forecasts for air quality conformity and SIP development.

2.0 Land Use, Demographic & Cost Data Development

The eight-county Houston-Galveston-Brazoria Consolidated Metropolitan Statistical Area (CMSA) has been federally designated as the Transportation Management Area (TMA) for the Houston-Galveston region. The Houston-Galveston TMA extends over an area of 7,809 square miles. Land Use and Demographic forecasts for the TMA are developed by H-GAC.

2.1 Zone System Definition

Under 1990 (census related) geography, H-GAC has designated 3,000 detailed traffic analysis zones (TAZs) in the Houston-Galveston TMA. This includes 2,954 internal zones and 46 external stations. The internal zones are entirely within the TMA and the external stations are used to capture external-external and external-local trips into and through the TMA.

2.2 Base Year Demographic Estimates

Estimated Year 2002 households and Year 2003 employment were used as the primary demographic inputs for the Year 2002 validation of the travel models. Estimates of 2002 household were derived through interpolation of year 2000 TAZ-level estimates and forecasted year 2007 TAZ-level data. Definitional changes to employment categories instituted as part of a new demographic forecast resulted in a situation in which future year forecasts of employment that will be used in conjunction this model set would be different than those of the Year 2002 employment data set. For this reason, employment estimates for the year 2003, which have consistent definitions to the future year employment were used in the validation of the Track-1 models. While use of the year 2003 employment results in a over-estimation of trip attractions, the H-GAC trip generation model scales attractions to match productions. Therefore, the total regional trip ends are the same as they would be if actual year 2002 employment was used.

2.3 Comparison of 1995 and 2002 Population/Household and 2003 Employment Estimates by County

Table 2.1 summarizes the household changes between 1995 and 2002. Region wide households increased over 14 percent, from 1.48 million in 1995 to nearly 1.70 in 2002. Household growth by county ranged from a low of 9.5 percent (Galveston) to a high of 38.0 percent (Montgomery). Table 2.2 summarizes the household population by county (which excludes group quarters such as prisons).

Table 2.1
County Households for 2002 and 1995

County	1995	2002	Change from 1995	% Change
Harris	1,120,750	1,238,400	117,650	10.5%
Brazoria	68,337	85,671	17,334	25.4%
Fort Bend	87,477	119,534	32,057	36.6%
Waller	9,027	11,006	1,979	21.9%
Montgomery	81,556	112,531	30,975	38.0%
Liberty	21,760	24,419	2,659	12.2%
Chambers	7,710	9,404	1,694	22.0%
Galveston	89,143	97,632	8,489	9.5%
Total	1,487,755	1,700,599	212,844	14.3%

Source: *Trip Generation Data for 2002 and 1995 prepared by H-GAC*

Table 2.2
County Household Population for 2002 and 1995

County	1995	2002	Change from 1995	% Change
Harris	1,120,750	1,238,400	117,650	10.5%
Brazoria	68,337	85,671	17,334	25.4%
Fort Bend	87,477	119,534	32,057	36.6%
Waller	9,027	11,006	1,979	21.9%
Montgomery	81,556	112,531	30,975	38.0%
Liberty	21,760	24,419	2,659	12.2%
Chambers	7,710	9,404	1,694	22.0%
Galveston	89,143	97,632	8,489	9.5%
Total	1,487,755	1,700,599	212,844	14.3%

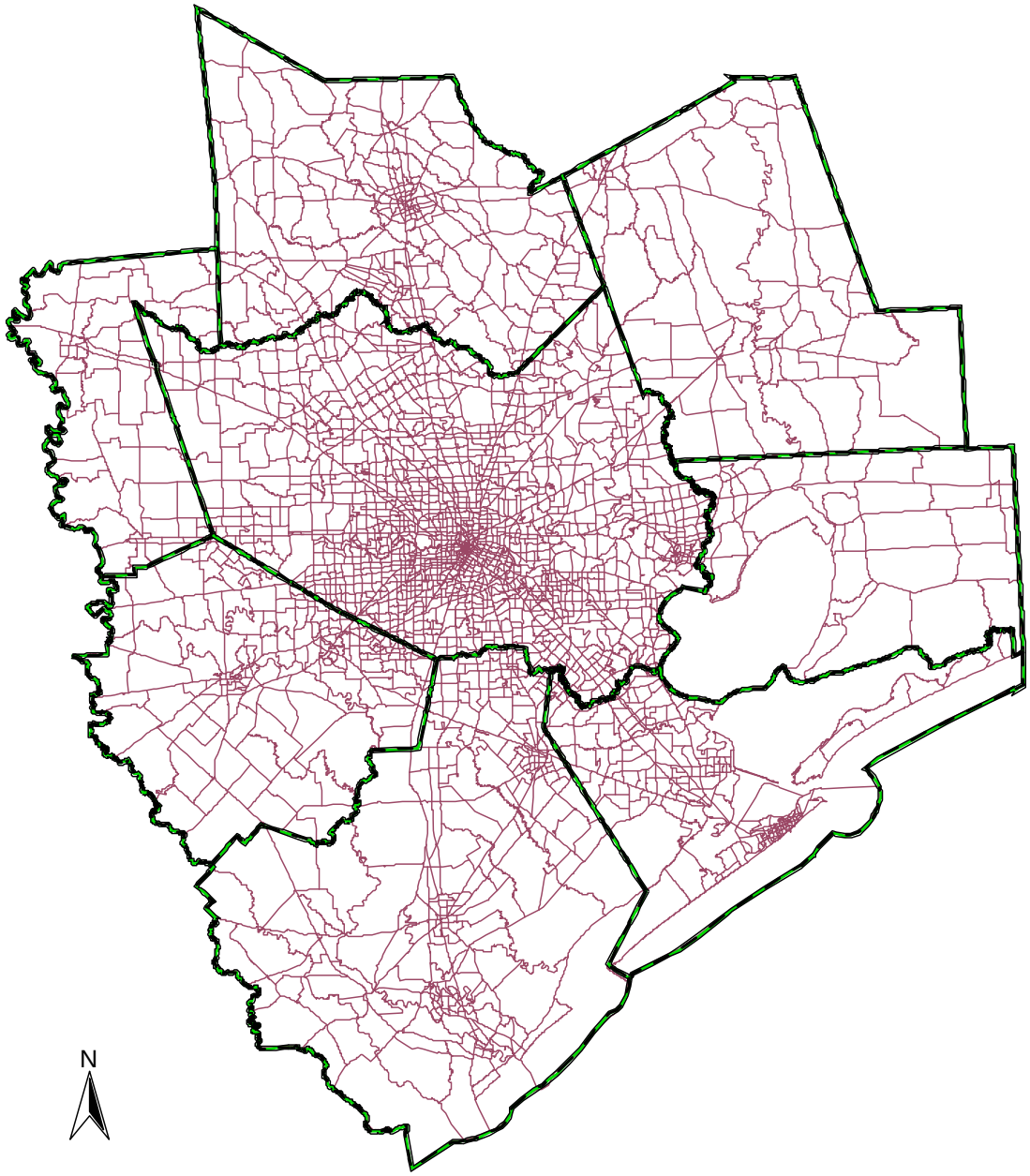
Source: *Trip Generation Data for 1990 and 1995 prepared by H-GAC*

Figure 2.1
Houston-Galveston-Brazoria Consolidated Metropolitan Statistical Area (Eight Counties)

Source: H-GAC

Figure 2.2

H-GAC Zone Structure



Source: H-GAC

Employment for the eight county region increased comparably with population growth, 18.5 percent overall (Table 2.3). Harris County gained over 300,000 additional jobs (a 19 percent

increase), while Fort Bend County employment grew more than 58 percent (over 42,000 jobs).

Table 2.3
County Employment for 1995 and 2003

County	1995 Employment	2003 Employment	Percent Change
Brazoria	74,327	81,727	10.1
Chambers	7,505	7,612	1.4
Fort Bend	72,804	115,553	58.7
Galveston	92,566	81,236	-12.2
Harris	1,687,630	2,010,409	19.2
Liberty	15,744	15,193	-3.5
Montgomery	70,276	85,638	21.9
Waller	9,577	7,612	-20.5
Total	2,030,429	2,405,613	18.5

Source: H-GAC Trip Generation Input Data for 1995 & 2002

2.4 Growth in Activity Centers Between 1995 and 2002/2003

Table 2.4 summarizes the household estimates for the four major activity centers. The Houston CBD showed a very high increase in households, more than tripling. The Texas Medical Center and Greenway Plaza centers experienced healthy increases, as well. The Uptown/Galleria area saw only a minor increase in the number of households between 1995 and 2002.

Table 2.4
Major Activity Center Households for 1995 and 2002

Major Activity Center	1995 Households	2002 Households	Percent Change
CBD	389	1,257	323.1
Texas Medical Center	853	969	13.6
Greenway Plaza	6,098	7,437	22.0
Uptown/Galleria	8,423	8,705	3.3

Source: *H-GAC Trip Generation Input data for 1995 & 2002*

2.5 Cost Data

2.5.1 Auto Operating Costs

Auto operating cost is an input to the mode choice model and is used by the model in establishing the costs for the auto-related choice paths available in the roadway network. This cost reflects costs that are assumed be variable costs including gas, oil, tires and maintenance. As part of the 2002 validation, auto operating costs were updated to a year 2002 value. This values was then converted to 1985 dollars to be consistent with the manner in which the mode choice model was calibrated. According to the Bureau of Transportation Statistics (BTS), auto operating cost in 2002 was 11.80 cents per mile. When deflated to 1985 dollars using the Bureau of Labor Statistics (BLS) National CPI data, the year 2002 cost in 1985 dollars is 7.06 cents.

2.5.2 Toll Costs

Toll costs are used in the mode choice model in the development of costs paths for the auto-related modal choices of the mode choice model. For toll facilities that existed in the Year 2002, the toll costs is assigned to the link in the network that represents the location where the toll is actually collected. Table 2.5 lists the Year 2002 toll costs in 1985 dollars.

Table 2.5
Year 2002 Toll Costs

Location	2002 Toll Cost 1985 Dollars
Hardy - North Plaza	0.47
Hardy - FM 1960 Ramp	0.41
Hardy - Richey Ramp	0.28
Hardy - Rankin Ramp	0.14
Hardy - South Plaza	0.48
Hardy - Bush IAH Ramp	0.28
Hardy - Greens Road Ramp	0.14
Hardy - Aldine Mail Ramp	0.41
Hardy - Little York Ramp	0.28
Hardy - Tidwell Ramp	0.17
Sam Houston North Plaza	0.48
Sam Houston North - SH 249 Ramp	0.41
Sam Houston North - North Gessner Ramp	0.28
Sam Houston North - Fallbrook Ramp	0.28
Sam Houston Central - West Road Ramp	0.14
Sam Houston Central Plaza	0.48
Sam Houston Central - Clay Road Ramp	0.28
Sam Houston Central - Hammerly Ramp	0.14
Sam Houston Southwest Plaza	0.48
Sam Houston Southwest - South Main (90-A)	0.14
Sam Houston Southwest – Hillcroft	0.19
Sam Houston Southwest - West Fuqua	0.28
Sam Houston Southwest – Almeda	0.41
Sam Houston South Plaza	0.48
Sam Houston South – Deerwood	0.28
Sam Houston South - Briar Forest	0.28
Sam Houston South – Westheimer	0.28
Sam Houston South – Bellaire	0.14
Sam Houston South - Beltway 8	0.19
Sam Houston Southeast Plaza	0.48
Sam Houston Southeast - Cullen	0.14
Sam Houston Southeast – Wayside	0.28
Sam Houston Southeast – Telephone Rd	0.19
Sam Houston Southeast – Monroe	0.14
Sam Houston East Plaza	0.50
Sam Houston East - Fairmont Parkway	0.41
Sam Houston East - Spencer Highway	0.28
Sam Houston East - Red Bluff	0.14

Source: H-GAC

2.5.3 Transit Fares

Year 2001 transit fares were used as transit fare inputs to 2002 validation. The 2001 fares were deflated to 1985 dollars. Table 2.6 presents the year 2001 transit fares, by service type, in 1985 dollars.

Table 2.6
Year 2001 Transit Fares
In 1985 Dollars

Local Bus	26
Express Bus	34
Commuter Bus	
< 5 Miles	68.29
5-10 miles	92.09
11-15 miles	115.89
> 15 Miles	139.69

Source: METRO

2.5.4 Parking Costs

Parking costs have been shown to have a significant effect on transit ridership levels and must be treated carefully. This variable is defined as an estimate of the actual (or average) out-of-pocket cost paid on a daily basis per vehicle. Table 2.7 summarizes the estimated parking costs used at the four major activity centers, including the Houston CBD, Greenway Plaza, Texas Medical Center, and Uptown/Galleria.

Table 2.7
Parking Costs for Activity Centers

Activity Center	Range of Costs	Average Cost
Houston CBD	$0.29-$6.73	$2.21
Greenway Plaza	$0.03-$1.30	$0.64
Texas Medical Center	$1.09-$2.06	$1.65
Uptown/Galleria	$0.07-$0.17	$0.10

Source: Houston METRO

3.0 Data Preparation and Transportation Network Development

Calibration and validation of the regional model was dependent upon observed travel behavior 1994 household, work place, commercial vehicle and external station travel surveys as well as a 1995 On-Board Transit Survey.

3.1 1994/1995 Travel Surveys

In 1994, H-GAC conducted a household travel survey for the Houston Metropolitan Area. The survey obtained general household and person data as well as specific activity-based trip information. Complete survey responses were obtained from 2,394 households, which generated in excess of 23,000 individual trip records.

The workplace travel survey involved the collection of travel data from employees and non-employees at 332 workplaces in the H-GAC region. Travel data was collected for over 5,000 employees and nearly 9,000 non-employees.

Surveying of external travel was performed at 24 of the 77 roadway crossings of the H-GAC region. The locations among the 77 were randomly selected and interviewed to determine vehicle destination.

3.2 Estimation of Highway Supply Characteristics

Highway supply characteristics that are required by the travel forecasting procedures include estimation of the highway level of service (LOS)(i.e., travel speed or time), parking costs, transit fares, terminal times, and auto operating costs.

The 2002 base year highway network includes key operational features for approximately 7,300 center-line miles of roadways in the Houston-Galveston TMA, and consists of nearly 17,000 roadway links (two-way, excluding centroid connectors). Each link's physical and operating characteristics are described in a link data record. The Base Year 2002 network was constructed from the model calibration year 1995 network based on completed project information and input from local transportation agencies. Access to the highway network is provided by connecting links referred to as centroid connectors, which link internal TAZ centroids to nodes (points) in the highway network. These centroid connectors represent access to collectors, arterials, and other roadway facilities via local streets. The physical and operational characteristics represented with centroid connectors reflect zone size, proximity to the regional highway network, and the travel characteristics of local roadway facilities, which have the function of providing access to land uses within zones.

Data on physical attributes of the network, including roadway length, number of lanes, and median access type (divided or undivided) as well as operational characteristics such as

average weekday traffic count and direction (one-way/two-way) were taken from the Roadway Inventory. Link data items such as facility type classification, 24-hour speed, and 24-hour capacity are derived either from the above information or from a vehicle trip assignment. Highway link facility types include nearly 40 different classifications. These are listed in Table 3.1 along with the link type codes for transit and HOV access.

3.2.1 Link Capacity

Capacity and speed are the two most critical inputs into the highway network. Capacity values accorded to all roadway links represent Level of Service (LOS) E or maximum capacity based on the Highway Capacity Manual.

The following formula provided the basis for calculation of 24-hour link capacities:

$$C_{24} = \frac{(PHPD + PHNP)}{K}$$

Where: C_{24} = average daily traffic, or 24-hour capacity;
PHPD = capacity in the peak direction during the peak hour;
PHNP = capacity in the non-peak direction during the peak hour;
K = design hourly volume as a percent of ADT.

The peak hour / peak direction and peak hour / non-peak direction capacities are then calculated as a function of the hourly saturation flow rate:

$$PHPD = \frac{CS \times \frac{G}{C} \times \frac{V}{C} \times PHF \times U \times \frac{L}{2}}{1 + (P_t(E_t - 1))} + LTVP$$

Where: CS = saturation flow rate (2,150 vehicles/hour/lane for freeways, 1,800 for arterials);
G/C = percent of green time at signalized intersections (100 percent for freeways);
V/C = ratio of volume in the peak 15 minutes to capacity;
PHF = peak hour factor (V (volume) in highest hour / 4 × V in the peak 15 minutes);
U = lane utilization factor;
L = number of lanes;
P_t = percent of trucks;
E_t = truck equivalency factor; and
LTVP = left turn volume in the peak hour and peak direction.

Table 3.1
Link Type Classification Codes

Code	Description

0	Centroid Connector
1	Radial freeways without frontage roads
2	Radial freeways with frontage roads
3	Circumferential freeways without frontage roads
4	Circumferential freeways with frontage roads
5	Radial tollways without frontage roads
6	Radial tollways with frontage roads
7	Circumferential tollways without frontage roads
8	Circumferential tollways with frontage roads
9	Principal arterials with some grade separations
10	Principal arterials – divided
11	Principal arterials – undivided
12	Other arterials – divided
13	Other arterials – undivided
14	One-way pairs
15	One-way facilities
16	Major Collectors
17	Minor Collectors
18	Ferries
19	Saturated arterials
20	HOV/transitways (barrier-separated)
21	HOV ramps – bus only
22	Transfers from park-and-ride (PNR) to transit stop
23	Transfers from local bus to commuter/express bus
24	Transfers from walk access node to transit stop
25	Drive-access connectors
26	Bus only: from street to transit center (TC)
27	HOV-only slip ramps
28	Transfer from pseudo-PNR to transit stop
29	HOV terminal ramps
30	Rail
40	High-Occupancy Toll (HOT) Lane
41	HOT ramp to PNR/TC
47	HOT slip ramp
49	HOT ramp
50	Freeway frontage road
51	Tollway frontage road
52	Freeway/tollway ramps to/from frontage roads
53	Freeway/tollway direct connector (DC) ramps
60	Diamond lane (non-barrier separated HOV lane)

Application of peak hour directionality factors to estimates of peak hour / peak direction volumes provides peak hour / non-peak directional volumes:

$$PHNP = PHPD \times \frac{1 - D}{D}$$

Where: D = percent of peak hour traffic in the peak direction.

3.2.2 Link Speeds & Automobile Travel Times

Link speed is used in trip distribution and as the input speed for the initial iteration in traffic assignment. The values of these link characteristics were carefully developed and closely reviewed during the speed model calibration process. Two speed values are developed for all roadway links: a 24-hour speed and a peak hour speed.

The 24-hour link speed reflects an average daily speed for a given roadway facility type within a given area. Reasonable speed values were determined by testing values through comparisons to travel time contours developed from observed travel times speeds.

After link speeds and capacities have been developed, they are compiled into a look-up table used for all roadway facility types except HOV / transitways. The look-up table (Table 3.2) provides classifications of speed and capacity by facility type and number of lanes. The table is not used for centroid connectors.

Table 3.2
Speed and Capacity Look-Up Table

		Area Type 1		Area Type 2		Area Type 3		Area Type 4		Area Type 5	
FT	Lanes	Capacity	Speed	Capacity	Speed	Capacity	Speed	Capacity	Speed	Capacity	Speed
1	4	123,500	48	128,000	48	119,500	51	106,500	54	69,000	59
1	6	185,500	48	191,500	48	179,500	51	159,500	54	103,000	59
1	8	247,500	48	255,500	48	239,500	51	212,500	54	137,500	59
1	10	309,500	48	319,500	48	299,500	51	266,000	54	172,000	59
1	12	371,000	48	383,500	48	359,000	51	319,000	54		
1	14	433,000	48	447,500	48	419,000	51				
1	16	495,000	48	511,000	48	479,000	51				
2	4	139,500	48	144,000	48	135,500	51	122,500	54	85,000	59
2	6	201,500	48	207,500	48	195,500	51	175,500	54	119,000	59
2	8	263,500	48	271,500	48	255,500	51	228,500	54	153,500	59
2	10	325,500	48	335,500	48	315,500	51	282,000	54	188,000	59
2	12	387,000	48	399,500	48	375,000	51	335,000	54		
2	14	449,000	48	463,500	48	435,000	51				
2	16	511,000	48	527,000	48	495,000	51				
3	4	117,000	48	130,000	48	125,500	51	109,500	54	78,000	59
3	6	176,000	48	195,500	48	188,000	51	164,000	54	117,500	59
3	8	234,500	48	260,500	48	251,000	51	218,500	54	156,500	59
3	10	293,000	48	325,500	48	313,500	51	273,000	54	195,500	59
3	12	351,500	48	390,500	48	376,000	51				
3	14	410,500	48	456,000	48	439,000	51				
3	16	469,000	48	521,000	48	501,500	51				
4	4	133,000	48	146,000	48	141,500	51	125,500	54	94,000	59
4	6	192,000	48	211,500	48	204,000	51	180,000	54	133,500	59

4	8	250,500	48	276,500	48	267,000	51	234,500	54	172,500	59
4	10	309,000	48	341,500	48	329,500	51	289,000	54	211,500	59
4	12	367,500	48	406,500	48	392,000	51				
4	14	426,500	48	472,000	48	455,000	51				
4	16	485,000	48	537,000	48	517,500	51				
5	4	79,000	55	78,000	55	73,000	58	68,000	61	58,000	65
5	6	119,000	55	117,000	55	109,000	58	102,000	61	86,000	65
5	8	158,000	55	156,000	55	146,000	58	136,000	61	115,000	65
5	10	198,000	55	195,000	55	182,000	58	171,000	61	144,000	65
5	12	238,000	55	233,000	55	218,000	58				
5	14	277,000	55	272,000	55	255,000	58				
5	16	317,000	55	311,000	55	291,000	58				
		Area Type 1		**Area Type 2**		**Area Type 3**		**Area Type 4**		**Area Type 5**	
FT	**Lanes**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**
6	4	93,500	55	95,000	55	89,000	58	83,000	61	69,000	65
6	6	133,500	55	134,000	55	125,000	58	117,000	61	97,000	65
6	8	172,500	55	173,000	55	162,000	58	151,000	61	126,000	65
6	10	212,500	55	212,000	55	198,000	58	186,000	61	155,000	65
6	12	252,500	55	250,000	55	234,000	58				
6	14	291,500	55	289,000	55	271,000	58				
6	16	331,500	55	328,000	55	307,000	58				
7	4	83,000	55	85,000	55	83,000	58	81,000	61	73,000	65
7	6	124,000	55	127,000	55	124,000	58	121,000	61	110,000	65
7	8	166,000	55	170,000	55	165,000	58	161,000	61	147,000	65
7	10	207,000	55	212,000	55	207,000	58	202,000	61	183,000	65
7	12	248,000	55	255,000	55	248,000	58				
7	14	290,000	55	297,000	55	289,000	58				
7	16	331,000	55	340,000	55	331,000	58				
8	4	97,500	55	102,000	55	99,000	58	96,000	61	84,000	65
8	6	138,500	55	144,000	55	140,000	58	136,000	61	121,000	65
8	8	180,500	55	187,000	55	181,000	58	176,000	61	158,000	65
8	10	221,500	55	229,000	55	223,000	58	217,000	61	194,000	65
8	12	262,500	55	272,000	55	264,000	58				
8	14	304,500	55	314,000	55	305,000	58				
8	16	345,500	55	357,000	55	347,000	58				
9	2	19,600	35	23,000	37	22,400	40	20,800	46	17,400	57
9	4	38,000	35	44,800	37	43,600	40	40,500	46	33,900	57
9	6	55,500	35	65,400	37	63,600	40	59,100	46	49,500	57
9	8	74,000	35	87,300	37	84,800	40	78,800	46	66,000	57
9	10			109,100	37	106,000	40	98,500	46	82,400	57
9	12			130,900	37	127,200	40	118,200	46	98,900	57
10	2	15,000	20	16,700	32	16,200	37	14,400	42	11,700	55

10	4	29,300	20	32,400	32	31,500	37	28,000	42	22,800	55
10	6	42,700	20	47,300	32	46,000	37	40,800	42	33,200	55
10	8	56,900	20	63,100	32	61,300	37	54,400	42	44,300	55
10	10			78,900	32	76,700	37	68,000	42	55,400	55
10	12			16,200	32	14,400	37	11,700	42	66,500	55
11	2	13,200	20	15,400	32	14,900	37	13,300	42	10,800	55
11	4	25,300	20	29,600	32	28,700	37	25,500	42	20,800	55
11	6	36,600	20	42,700	32	41,500	37	36,900	42	30,000	55
11	8	48,200	20	56,300	32	54,700	37	48,600	42	39,600	55
11	10			69,200	32	67,300	37	59,800	42	48,800	55
11	12			81,800	32	79,500	37	70,600	42	57,700	55
		Area Type 1		**Area Type 2**		**Area Type 3**		**Area Type 4**		**Area Type 5**	
FT	**Lanes**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**
12	2	13,500	20	16,200	32	14,600	36	12,500	40	10,500	51
12	4	26,300	20	31,500	32	28,400	36	24,400	40	20,500	51
12	6	38,400	20	45,900	32	41,500	36	35,600	40	29,900	51
12	8	51,200	20	61,300	32	55,300	36	47,400	40	39,900	51
12	10			76,500							
12	12			91,900							
13	2	12,500	20	15,100	31	13,600	35	11,700	39	10,200	50
13	4	24,100	20	29,000	31	26,200	35	22,500	39	19,500	50
13	6	34,700	20	41,900	31	37,900	35	32,500	39	28,200	50
13	8	45,800	20	55,200	31	49,900	35	42,800	39	37,200	50
13	10			67,900	31	61,400	35	52,700	39	45,800	50
13	12			80,200	31	72,500	35	62,200	39	54,100	50
14	2	14,800	20	17,300	34	16,400	38	14,500	41	11,900	55
14	4	29,500	20	34,600	34	32,800	38	29,000	41	23,900	55
14	6	43,300	20	50,700	34	48,000	38	42,400	41	35,000	55
14	8	56,300	20	66,000	34	62,500	38	55,200	41	45,500	55
14	10	70,400	20	82,500	34	78,100	38	69,000	41	56,900	55
14	12	84,500	20	99,000	34	93,700	38	82,800	41	68,300	55
14	14	98,600	20	115,500	34	109,300	38	96,600	41	79,700	55
14	16	112,600	20	132,000	34	124,900	38	110,400	41	91,100	55
15	1	7,400	20	8,700	34	8,200	38	7,200	41	6,000	55
15	2	14,800	20	17,300	34	16,400	38	14,500	41	11,900	55
15	3	21,600	20	25,400	34	24,000	38	21,200	41	17,500	55
15	4	28,200	20	33,000	34	31,200	38	27,600	41	22,800	55
15	5	35,200	20	41,300	34	39,000	38	34,500	41	28,500	55
15	6	42,200	20	49,500	34	46,800	38	41,400	41	34,100	55
15	7	49,300	20	57,800	34	54,700	38	48,300	41	39,800	55
15	8	56,300	20	66,000	34	62,500	38	55,200	41	45,500	55
16	2	12,500	19	14,600	31	13,200	35	11,400	38	8,800	49
16	4	24,100	19	28,200	31	25,500	35	21,800	38	16,900	49
16	6	34,700	19	40,600	31	36,800	35	31,600	38	24,400	49

16	8	45,800	19	53,600	31	48,400	35	41,600	38	32,100	49
16	10	53,300	19								
17	2	8,700	18	10,400	28	10,200	33	8,900	36	7,400	46
17	4	16,200	18	19,300	28	18,900	33	16,600	36	13,700	46
17	6	24,100	18	28,300	28	27,800	33	24,400	36	20,200	46
17	8	33,900	18	39,800	28	39,100	33	34,400	36	28,300	46
19	2	19,000	20	21,600	32	21,200	37	20,800	42	15,300	55
19	4	37,800	20	43,000	32	42,200	37	41,400	42	30,600	55
		Area Type 1		**Area Type 2**		**Area Type 3**		**Area Type 4**		**Area Type 5**	
FT	**Lanes**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**	**Capacity**	**Speed**
19	6	56,400	20	64,200	32	63,000	37	61,800	42	45,600	55
19	8	74,800	20	85,100	32	83,500	37	81,900	42	60,500	55
19	10			106,400	32	104,400	37	102,400	42	75,600	55
19	12			127,700	32	20,800	37	15,300	42	90,700	55
50	1	6,600	20	7,800	27	7,050	31	6,050	35	5,100	42
50	2	12,850	20	15,150	27	13,700	31	11,750	35	9,950	42
50	3	17,600	20	20,700	27	18,700	31	16,050	35	13,550	42
50	4	22,700	20	26,750	27	24,150	31	20,700	35	17,500	42
51	1	6,300	20	7,450	32	6,750	35	5,750	40	4,900	45
51	2	12,250	20	14,450	32	13,050	35	11,200	40	9,500	45
51	3	17,000	20	20,050	32	18,100	35	15,500	40	13,100	45
51	4	21,950	20	25,850	32	23,350	35	20,000	40	16,900	45
52	1	17,150	20	19,250	27	18,050	31	15,850	35	13,000	42
52	2	34,300	20	38,500	27	36,100	31	31,650	35	26,000	42
53	1	17,150	45	19,250	45	18,050	50	15,850	50	13,000	50
53	2	34,300	45	38,500	45	36,100	50	31,650	50	26,000	50
53	3	51,450	45	57,750	45	54,150	50	47,500	50	39,000	50
53	4	68,600	45	77,050	45	72,250	50	63,350	50	52,000	50
53	5	85,750	45	96,300	45	90,300	50				
53	6	102,900	45	115,550	45	108,350	50				

Source: H-GAC

Time-of-day highway speeds that are used to develop automobile travel times are based on procedures adapted from the *Highway Capacity Manual* (HCM) methodology. These procedures differ somewhat between how freeway and non-freeway link speeds are estimated. Congested freeway speed is a function of free-flow speed (a function of speed limit and area type), speed at capacity (LOS E), and the volume-to-capacity (v/c) ratio for v/c ratios up to 1.0. For v/c ratios greater than 1.0, which represents saturated (LOS F) conditions, speed is estimated using a variant of the BPR function, with a multiplicative factor of 0.15 and v/c raised to the fourth power.

Procedures outlined in the HCM are used to estimate congested speeds on arterial or collector links. Congested arterial/collector link speed is a function of free-flow speed (a function of speed limit and area type), average intersection delay, signal spacing (segment), and the ratio of segment running time per mile to free-flow-speed running time per mile, where v/c ratios are 1.0 or less. For saturated (LOS F) conditions with v/c ratios greater than 1.0, speed is estimated using a variant of the BPR function, with a multiplicative factor of 0.15 and v/c raised to the second power.

Peak period speeds are derived from a peak period equilibrium assignment. Since capacities used during the equilibrium assignment represent LOS E, the resulting link's V/C ratio can then be applied to the speed model to develop a peak hour speed. In other words, the traffic assignment results are post-processed to compute a reliable speed based on the assigned V/C ratio.

3.2.3 Auto Network Centroid Connectors

Speeds on centroid connectors are derived as a function of link length and zonal area type to reflect diversity in zone size, network density, and local street operational speeds. As an example, centroid connectors of less than one-tenth mile within the Houston CBD are assigned a speed of eleven miles per hour, which is considered the lowest practical facility speed that would not unduly penalize travel in that area.

CBD centroid connector speed is increased based on link length (for links less than one-tenth mile) as follows:

Travel Time (minutes) = (6.0 * link distance)
Travel Speed = 60 / (Travel Time / link distance)

For CBD centroid connectors longer than 0.10 miles, the speed is calculated as follows:

Travel Time (minutes) = (0.6 + 4 * (link distance - 0.1))
Travel Speed = 60 / (Travel Time / link distance)

As the area changes from CBD to urban to suburban, etc., centroid connector speeds increase more rapidly with increasing distance. This is based on the premise that as area type changes from denser areas (CBD) to less dense areas (suburban) zone sizes will increase accordingly. Thus, each of the other four area types have a unique set of equations for determining centroid connector speeds:

Area Type 2 - Urban

when link distance = 0.10 miles or less:
Travel Time (minutes) = (4.0 * link distance)
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.10 miles and <= 0.25 miles:
Travel Time (minutes) = (0.4 + 3 * (link distance - 0.1))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.25 miles:

Travel Time (minutes) = (0.85 + 2.4 * (link distance - 0.25))
Travel Speed = 60 / (Travel Time / link distance)

Area Type 3 - Suburban

when link distance = 0.10 miles or less:
Travel Time (minutes) = (4.0 * link distance)
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.10 miles and <= 0.25 miles:
Travel Time (minutes) = (0.4 + 3 * (link distance - 0.1))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.25 miles and <= 0.50 miles:
Travel Time (minutes) = (0.85 + 2.4 * (link distance - 0.25))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.50 miles:
Travel Time (minutes) = (1.45 + 2.0 * (link distance - 0.5))
Travel Speed = 60 / (Travel Time / link distance)

Area Type 4 - Fringe Suburban

when link distance = 0.10 miles or less:
Travel Time (minutes) = (3.5 * link distance)
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.10 miles and <= 0.25 miles:
Travel Time (minutes) = (0.35 + 2.7 * (link distance - 0.1))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.25 miles and <= 0.50 miles:
Travel Time (minutes) = (0.755 + 2.2 * (link distance - 0.25))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.50 miles and <= 0.75 miles:
Travel Time (minutes) = (1.305 + 1.8570 * (link distance - 0.5))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.75 miles:
Travel Time (minutes) = (1.76925 + 1.714 * (link distance - 0.75))
Travel Speed = 60 / (Travel Time / link distance)

Area Type 5 - Rural

when link distance = 0.10 miles or less:
Travel Time (minutes) = (3.0 * link distance)
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.10 miles and <= 0.25 miles:

Travel Time (minutes) = (0.30 + 2.4 * (link distance - 0.1))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.25 miles and <= 0.50 miles:
Travel Time (minutes) = (0.66 + 2.0 * (link distance - 0.25))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.50 miles and <= 0.75 miles:
Travel Time (minutes) = (0.96 + 1.714 * (link distance - 0.5))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 0.75 miles and <= 1.0 mile:
Travel Time (minutes) = (1.3885 + 1.5 * (link distance - 0.75))
Travel Speed = 60 / (Travel Time / link distance)

when link distance > 1.0 mile and <= 1.5 miles:
Travel Time (minutes) = (1.7035 + 1.333 * (link distance - 1.0))
Travel Speed = 60 / (Travel Time / link distance)

For rural zones exceeding 1.5 miles, link speeds are calculated as follows:

Travel Time (minutes) = (2.37 + 1.2* (link distance - 1.5))
Travel Speed = 60 / (Travel Time / link distance)

Thus, an urban zone may have a link distance of 1.0 mile yielding a speed of 22.6 miles per hour, while a suburban zone of 1.0 mile has a speed of 41.4 miles per hour. A representative table (Table 3.3) of centroid connector speeds for a distance of one mile would appear as follows:

Table 3.3
Centroid Connector Speeds

Area Type	Distance (miles)	Speed (mph)
CBD	1.0	14.3
Urban	1.0	22.6
Suburban	1.0	24.5
Fringe Suburban	1.0	27.3
Rural	1.0	32.6

Source: H-GAC

3.2.4 HOV Facilities

In 2002, barrier-separated HOV lanes existed in the following freeway corridors; these are:

- Katy Freeway
- Northwest Freeway
- North Freeway
- Eastex Freeway
- Gulf Freeway
- Southwest Freeway

Additionally, non-barrier separated HOV lanes or Diamond lanes existed in these freeway corridors

- Katy Freeway
- Southwest Freeway

Unique links are included in the highway network to represent each of the HOV facilities including ramps and connector links to park-and-rides and transit centers.

3.2.5 Toll Road Facilities

In the 2002 network, toll roads are coded comparably to any freeway link. The actual toll imposed on a vehicle is stored in a user-specified link field and accumulated into a separate toll matrix during the assignment process. Separate toll plaza links are included in the network specifically for this purpose. There are two freeways currently designated as toll roads; these are:

- Hardy Toll Road
- Sam Houston Tollway

There is an additional network link representing the Houston Ship Channel Bridge which also charges a toll.

3.2.6 Auto Modes

In emme/2, all network links contain one or more single letter identifiers for each mode allowed to traverse that link. In order to remain consistent with the choice structure of the mode choice model and facilitate use of the multi-class assignment within emme/2, the following six codes were used in the base or roadway network:

- l SOV non-toll
- m SOV toll
- h 2-person non-toll
- I 2-person toll
- j 3+ person non-toll
- n 3+ person toll

3.2.7 Additional Highway Characteristics

Highway terminal time represents the time required to walk from a selected parking space to the ultimate destination of a trip. Historically, terminal time has been determined synthetically by relating the density of employment to the magnitude of the value, that is, the greater the employment density, the higher the value of terminal time. This underlying concept is supported by the fact that as employment density increases, parking supply typically decreases, costs influenced by demand increase, and trip makers begin to "trade-off" walking distance with the availability and price of parking. Currently, terminal times vary from six minutes in the CBD to a low of two minutes in residential areas.

Auto operating costs are an estimate of the out-of-pocket cost paid to operate a private vehicle on a per-mile basis. Cost components included in this variable are based upon fuel cost and fuel economy plus tire, oil, and general maintenance costs. Fixed elements of cost, such as depreciation and insurance costs, are not considered out-of-pocket costs.

3.3 Estimation of Transit Supply Characteristics

A reflection of the level-of-service experienced by a potential transit user is constructed through development of a computerized network representation of the system of routes and service levels. This computer-coded transit network must be an accurate representation of the individual bus routes, fixed guideway lines, headways, and travel times that define that service. Consistency in representation methods across all alternatives is essential to ensure that differences in travel times between those alternatives are accurate portrayals of service level differences, and not simply differences in coding conventions.

Reflection of the choice of "path" or route(s) selected between TAZ's within the network is an equally important consideration in properly determining transit supply characteristics. The algorithm which applies the "path-building" step of the process must examine all the possible ways in which a transit user could travel on one or more transit lines between each pair of TAZ's. This algorithm selects the path that involves the minimum inconvenience in terms of in-vehicle time, waiting, transferring, and accessing the service.

3.3.1 Transit Routes and Coded Lines

A route in the transit system is typically a set or series of services that operate generally in the same area and over the same streets, but which may offer variations in service origination or termination. The path-building algorithm, however, must be aware of the specific service level options available to each TAZ zone pair, which, therefore, necessitates the representation of each of the variations within a route by means of a separately coded line. Similarly, not all routes or subroutes operate during the course of the entire day. Express and Commuter routes, in particular, generally operate only during the morning and afternoon peak periods. In order to properly reflect these differences, separate peak and base networks are constructed for use in the travel forecasting process.

A trade-off exists between the precision of representation of individual route variations actually operated and the transit service levels perceived by transit users. This tradeoff stems from the manner in which the path-building algorithm measures the frequency of service between boarding and alighting locations. The algorithm recognizes that several lines operating in the same pattern offer a combined frequency of service that is the summation of the frequencies on each individual line. In contrast to other modeling software packages where this recognition occurs only when the lines follow *exactly* the same routing, emme/2 allows combined service computation for coded transit network lines that comprise variations in routing or termini.

3.3.2 Headway Calculation

Specification of service frequency for each coded line is an extremely important aspect of the overall network coding process. As outlined above, service is differentiated both by delineation of individual lines (within routes) and also by time period (peak and base). The determination or calculation of a headway value for each line within a time period is related directly to the actual number of bus trips operated.

In the case of the base or off-peak period, the headway is simply the number of hours in the mid-day period divided by the total number of trips provided on that line during mid-day.

Unlike base period service, which tends to be fairly evenly distributed over the entire period, peak service may vary substantially within the peak period. Express lines, for example, may provide relatively few bus trips over the entire period, but may concentrate these trips within a

relatively small time interval. Assuming that these trips are appropriately targeted to the specific demand for peak period service, the perceived headway by riders (who will become familiar with the scheduling of the service) will be significantly better than the value implied by using a computation method identical to that for base period service. Therefore, peak headway calculations must be based upon the peak hour of service offered in the peak period, with an appropriate peak hour headway calculated. Table 3.4 summarizes the coded peak and base period headways for each of the lines coded in the transit network.

This approach to coding produces headway values appropriate for the ridership forecasting process, but typically overestimates peak resource requirements: vehicles, vehicle-hours, and vehicle-miles. A separate analysis of resource requirements is conducted in a post-processing environment to resolve this inconsistency.

3.3.3 Transit Travel Times

travel times are based on: automobile travel times, type of transit service (local, limited, express, etc.), and bus location by sector. The running time of the transit lines over all the network links in each line is calculated using a series of travel time functions (TTF) based on these parameters. Each TTF is referenced with a designated number. Three basic types of TTFs are included in the model:

I. Simple assumed speed

II. Auto speed multiplied by an auto-to-transit time factor

III. Congested speed estimation using BPR function, based on free-flow transit speed compared to minimum transit speed.

Type I TTFs are coded with an assumed speed, which is constant across all links. Type II TTFs apply a multiplicative factor to auto time to relate transit link travel time to the corresponding auto travel time. Type III TTFs estimate congested-speed travel time based on free-flow transit travel time and the v/c ratio of the link. The general form of Type III TTFs is the BPR function, that is:

$$t_c = t_{ff} \times \left(1 + \alpha \times \left(v/c\right)^4\right)$$

where t_{ff} is free-flow transit travel time, and α is a multiplicative factor. For all but two TTFs, α is 0.10. For those two TTFs representing nonstop bus operations outside the CBD, α is 0.15. Congested-speed travel time is capped against a maximum time associated with a given minimum transit speed and the resulting time is compared to a minimum time representing auto time on the same link. All three TTFs are used during the peak period, while only Types I and II are used during the off-peak period.

A summary of the peak travel time functions are presented in Table 3.5.

Table 3.4
2002 Transit Line Coded Headways

Route	Name	Peak Headway	Base Headway
		(minutes)	(minutes)
1a	Hospital	15	18
2a	Bellaire-Mission Ben	10	30
2b	Bellaire-Westchase	30	30
2c	Bellaire-7600 Turn B	30	60
3a	Langley LTD./West Gr	15	30
4a	Beechnut/Jensen Via	8	30
4b	Beechnut-Jensen W.Loop	16	60
5a	Kashmere Gardens/Sou	15	15
5b	Kashmere Gardens/GSH	15	15
8a	W. Bellfort-CBD	10	15
8b	N.Main/S.Main-Willow	20	30
11a	Nance/Almeda	25	35
15a	Hiram Clark Transit	8	15
15b	Hiram-Orem/Fulton	16	15
17a	Tanglewood/Gulfton	20	20
18a	Kirby Lake 610-West	32	40
19a	Wilcrest Crosstown	15	45
20a	Canal/Long Point-Mem	28	40
20b	Canal/Long Point-Neu	28	40
20c	CBD-Long Point-Memor	120	40
23a	Crosstimbers-xtown	27	27
25a	Rich N.Line W.Chase	24	60
25b	Rich N.Line Sharptwn	24	60
26a	Outer Loop-Clockwise	20	30
26b	Outer Loop-Counter	20	30
29a	SU/UH Hirsch Xtown	18	18
30a	Galena Port-CullenVF	60	30
30b	Clinton-Cullen FWY	40	30
30c	Denver Harbor-Cullen	40	30
33a	P.Oak Xtown Ridgmont	25	25
33b	Post Oak-W. Fuqua	25	25
34a	Montrose Xtown	25	45
35a	Fairview-2000/Leelan	30	45
36a	Kempwood-9800 CBD vi	30	60
36b	Kempwood-Carverdale	30	60
37a	El Sol Xtown	35	35
40a	Pecore NW.Mall-Richy	30	60
40b	Pecore AHTC-Howard	30	60
40c	Howard-AHTC Via FWY	60	60
40d	Richey-CBD	60	60
41a	Gulf Medows Circ	40	40
42a	Holmn Xtwn-Dnvr Hbr	30	30
42b	Holman-EWTC	30	30
43a	Pinemont Plaza	30	55
44a	Acr Home-Compaq	20	30
44b	Stallings-CBD	40	60
45a	Tedwell Xtown	20	40
46a	Gessener Xtown	12	30

47a	Hillcroft Xtown	20	25
48a	Navig-Gulfgate/W. Da	60	60
48b	Navig-Plsntvil/W. Da	30	60
49a	Chimney Rock Xtown	40	50
50a	Heights CBD-FWY	60	60
50b	Heights Rosl-Airport	40	40
50c	Heights Hollister-Do	50	50
50e	Heights 4200-Airport	120	120
50f	Heights 4200-Dock	90	90
52a	Hirsch/Scott-8000	60	60
52b	Hirsch/Scott	40	40
52c	Scott-CBD via FWY	40	40
53a	Westheimer Briar For	18	50
53b	Westheimer-W. Oaks	18	--
54a	Hollyvale Circ	30	50
56a	Airline Greens FWY	12	15
58a	Hammerly-CBD FWY	60	60
58b	Hammerly-NWTC	20	60
60a	Hardy/S.MacGregor	30	60
64a	Lincoln City Circ	30	60
65a	Dairy Ash-Blue Bell	40	40
65b	Dairy Ash-Sweetwater	40	40
65c	D.A. FWY-Blue Bell	90	90
65d	D.A. FWY-Sweetwater	90	90
65e	D.A. FWY-CBD	80	--
65f	D.A. Local-CBD	20	20
67a	Dairy Ashford Xtown	30	60
68a	Brays Bayou W. belt	24	60
68b	Brays Bayou Meado	24	60
70a	University	45	--
72a	Westview	25	25
73a	Bellfort Xtown P.Oak	30	40
73b	Bellfort Xtown TMC	8	20
77a	Wayside-MLK	22	60
77b	Homestead-MLK	22	60
77c	MLK-CBD	15	60
78a	Alabama Irvin 9800	40	60
78b	Irvin 9800-CBD	15	60
79a	West Little York LTD	35	35
80a	Lyons Dowling	20	30
80b	Lyns-Keley/Dowlng-HK	20	30
82a	Westheimer-Woodlake	30	60
82b	Westheimer-Sharptown	10	20
83a	Lee Road Circ	30	50
84a	TC Jester Ltd	20	--
85a	Antoine-CBD via Wash	40	60
85b	Antoine-CBD via I-10	8	60
86a	FM 1960 Circ-NHCC	30	60
86b	FM 1960-Greenspoint	30	60
87a	Yellowstone Circulat	20	35
89a	South Park Circulato	35	60
93a	NWTC-GWY Shuttle	20	--

97a	Settegate Shuttle	60	60
98a	Briargate	35	35
101a	Airport	15	50
102a	IAH-CBD Express	12	40
102b	Greens-CBD	60	60
108a	Vet-Memorial Express	18	35
132a	Harwin Exp Mission	15	50
132b	Harwin Exp Mission	30	50
132c	Harwin Exp Cook RD	30	60
137a	Northshore Exp	20	40
163a	Foundren-Airport	20	40
163b	Foundren-MC P&R	20	40
170a	Missouri City Exp	10	--
201a	N.Sheph P&R-Cull CTR	15	--
201c	N.Sheph P&R-Hous CTR	25	--
202a	Kuyk P&R Houstn Ctr	8	35
202b	Kuyk P&R Houstn Ctr	30	--
205a	Kingwood P&R	10	40
205b	Kingwood-Houston Ctr	30	--
206a	Eastex P&R	12	40
212a	Seton Lake Via TC	30	--
212b	Seton Lake P&R	10	--
214a	N.West Station P&R	14	--
214b	N.West Station P&R	14	40
216a	W.Little York-Pine	20	--
216b	W.Little York-Pine	20	40
221a	Kingland P&R Kty/CBD	5	45
221b	Kgld-Addi-NWTC P&R	30	--
228a	Addicks P&R	8	45
236a	Maxey Rd P&R	16	--
236b	Maxey Rd P&R	160	--
244a	Monroe P&R	15	15
244b	Monroe P&R EWTC	60	50
246a	Bay Area P&R	10	--
246b	Bay Area P&R	60	--
246c	Bay Area P&R EWTC	45	--
246d	Combined 245/246 P&R	--	50
247a	Fuqua P&R	10	--
247b	Fuqua P&R EWTC	20	--
261a	West Loop P&R	10	50
261b	West Loop P&R	10	**--**
262a	Alief-W.Wood P&R	10	**--**
262b	Alief-W.Wood Houst C	30	--
265a	W.Belfort P&R	12	--
265b	W.Bellfort P&R	12	--
273a	Gessner P&R	15	--
283a	Kuykendahl/Uptown P&R	15	--
284a	Kingwood/Uptown P&R	20	--
285a	Kglsnd/Addi/Uptown	15	--
285b	Kglsnd/Addi/Uptown	30	--
286a	W.Little York-Uptown	30	--
286b	W.Little York-Uptown	30	--

291a	Kuyk/N.Sheph P&R-TMC	15	--
292a	W.Bellfort-TMC P&R	15	--
297a	S.Pt/Monron-TMC P&R	15	--
298a	Addicks-TMC P&R	10	--
320a	TMC Gold	3	3
321a	TMC Blue	5	5
323a	TMC Green	4	4
451a	Trolley Route A	10	10
452a	Trolley Route B	10	10
453a	Trolley Route C	7	7
454a	Trolley Route D	12	12
455a	Trolley Route E	12	15
601a	Sawdust-CBD	10	--
601b	Sawdust-GRWY	10	--
601c	Sawdust-TMC	10	--

Source: H-GAC

Table 3.5
Peak Transit Travel Time Functions

TTF	Type	Operation	Location	Type I	Type II	Type III	
				Assumed Speed	Auto-to-Transit Time Factor	Free-flow Transit Speed	Minimum Transit Speed
10	III	All Stop	Inside CBD			9	5
11	II		Transit Mall		1.0		
12	III		Inside 610 Loop			18	10
13	III		Outside 610 Loop			20	12
20	III	Limited Stop	Inside CBD			10	6
21	II		Transit Mall		1.0		
22	III		Inside 610 Loop			22	13
23	III		Outside 610 Loop			30	14
30	III	Non Stop	Inside CBD			12	7
31	II		Transit Mall		1.0		
32	III		Inside 610 Loop			40	n/a
33	III		Outside 610 Loop			45	n/a
8	I		Transit Ramp	12			
9	I		Transitway	53			

Source: 1990 Houston Long-Range Patronage Forecasting Model Validation

3.3.4 Transit Path Building

Path building between each pair of zones relies upon the coded representation of the transit network as outlined above and a set of "weights" used to value each time component of the trip—walking, waiting, in-vehicle, and transferring. To the greatest extent possible, these weights should be reasonably similar to the "weight" derived from the mode choice model relationships.

The set of path building weights below was the final set of values used in the 1990 validated model (all times are in minutes):

- Boarding time: 1.0
- Boarding time weight (drive access): 1.0
- Boarding time weight (walk access): 10.0
- Waiting time factor: 0.5
- Waiting time weight: 2.0
- Auxiliary transit time weight: 1.5

3.3.5 Transit Modes

In emme/2 all network links contain a single letter identifier for each mode allowed to traverse the link. Auxiliary transit modes are defined as walk and auto access modes; these modes represent access to, from, and between transit lines and constitute a portion of a transit trip. The following transit modes were used:

- b: local bus
- c: commuter bus
- x: express bus
- r: rail

The auxiliary transit modes are:

- d: walk access to transit
- e: walk egress to transit
- t: transfer between transit lines
- p: auto access to transit (park-and-ride lots)
- k: auto access to transit (kiss-and-ride lots)
- q: auto access to transit (informal park-and-ride lots)
- w: sidewalk

4.0 Travel Forecasting Procedures

4.1 Introduction

This chapter presents the underlying theory and basis for the structure, formulation, and application of each model component. Also described is the series of steps that were followed to enhance and implement the revised regional mode choice model set, as well as the calibration and validation procedures performed to verify the accuracy and acceptability of the complete model set.

Two key sets of data are input to the model: 1. demographic, socioeconomic and landuse data, and 2. the multimodal transportation network data. In the first stage of the modeling process--trip generation--estimates are developed for fourteen trip purposes:

- Home-based Work person trips (HBW);
- Home-based Nonwork person trips to Retail (HBNW-RET)
- Home-based Nonwork person trips to ED1 (HBNW-ED1)
- Home-based Nonwork person trips to ED1 by School Bus (HBNW-SCHBUS)
- Home-based Nonwork person trips to Airport (HBNW-AIR)
- Home-based Nonwork person trips to Other (HBNW-OTHER)
- Non-home-based person trips – Workbased (NHB-WB);
- Non-home-based person trips – Non-workbased (NHB-NW);
- Taxi vehicle trips (TAXI);
- Truck vehicle trips (TRUCK);
- External-Local Auto trips (EXTL-AUTO);
- External-Local Truck trips (EXTL-AUTO);
- External-Through Auto trips (EXTHR-AUTO);
- External-Through Truck trips (EXTHR-TRUCK).

The Home-based Nonwork person trips to ED1 (HBNW-ED1) trip purpose excludes the person trip by school bus but includes those that use normal transit. The Home-based Nonwork person trips to ED1 by School Bus (HBNW-SCHBUS) is defined as a separate trip purpose in the model set. This was necessary since the mode choice model used in the model set assumes that the person trips by school bus have been removed from the data which is input to the mode choice step. As can be seen in the trip purpose definitions, the non-work person trip purposes are defined around the land use and the attraction end of the trip. Also, non-home-based trips have been separated into those that in which the production is the trip-makers place of employment (work-based) and those in which the production is not the trip makers place of employment (not work-based).

4.2 Trip Generation

Trip generation is performed with a trip production model and a trip attraction model for each trip purpose. These models use the zonal demographic data to estimate the overall magnitude of trip making, that is, the total number of trip ends (trip productions and trip attractions), for each of the 2,954 detailed traffic analysis zones. Trip estimates by purpose are also prepared for the 46 external stations.

4.2.1 Trip Production

The H-GAC trip household production models use cross-classification trip production rates developed from the H-GAC 1995 Household Travel Survey data. These rates were developed for a two-way cross classification model of household size by household income. Individual cell values in the two way cross classification table were derived by computing the average of the expanded household travel survey for each cell. In the model calibration process, some of the resulting rates are smoothed to removed sampling noise due to the small sample sizes being employed. The resulting production rates (i.e., the dependent variables) are the trips per household by purpose. Cross-classification models allows the nonlinearity of the model with respect to the independent variables. This is a standard practice approach for developing household trip production models.

The trip production model determines the relationship between trips generated per household and household income in combination with household size. Thus, trip production rates are stratified by household income and household size for each trip purpose and are presented in Tables 4.1-4.8.

Due to the high concentration of hotels, motels, and seasonal housing in the Galveston Island area, generation of non-resident trips is also performed.. Based on area specific monthly hotel/motel occupancy rates an average rate was applied against the number of units in the Galveston Island area to estimate occupied rooms; this estimate of rooms was multiplied by a NHB trip rate to determine the number of non-resident hotel/motel NHB trips. Likewise, an occupancy rate for seasonal housing factored by a NHB trip rate yielded seasonal housing non-resident NHB trips.

Table 4.1
Home-Based Work Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.406	1.033	1.846	1.993	1.993
2	1.049	1.442	2.247	2.455	2.455
3	1.079	1.842	2.247	2.453	2.434
4	1.243	1.843	2.256	2.453	2.434
5+	1.243	1.987	2.624	2.624	2.707

Source: H-GAC

Table 4.2
Home-Based Non-Work to Education-1 (K-12th) Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.086	0.169	0.641	1.262	2.759
2	0.112	0.346	0.978	1.740	3.102
3	0.119	0.268	1.075	2.436	3.411
4	0.048	0.193	1.171	2.714	3.801
5+	0.101	0.141	1.441	3.211	4.497

Source: H-GAC

Table 4.3
Home-Based Non-Work to Educational-1 (K-12th) by School Bus Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.000	0.040	0.478	0.712	1.017
2	0.000	0.040	0.478	0.712	1.092
3	0.000	0.044	0.339	0.609	1.128
4	0.000	0.044	0.201	0.609	1.164
5+	0.000	0.031	0.225	0.631	1.142

Source: H-GAC

Table 4.4
Home-Based Non-Work to Retail Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.743	1.347	1.684	1.725	2.239
2	0.877	1.553	1.684	2.094	2.892
3	0.877	1.553	1.691	2.318	3.021
4	0.824	1.516	1.691	2.684	3.251
5+	0.824	1.516	2.120	2.923	4.144

Source: H-GAC

Table 4.5
Home-Based Non-Work to Airport Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.014	0.026	0.033	0.039	0.051
2	0.009	0.022	0.033	0.041	0.059
3	0.011	0.021	0.031	0.043	0.057
4	0.011	0.019	0.027	0.046	0.055
5+	0.018	0.022	0.027	0.048	0.057

Source: H-GAC

Table 4.6
Home-Based Non-Work Other Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.744	1.402	1.779	2.122	2.798
2	0.499	1.174	1.779	2.212	3.186
3	0.574	1.159	1.690	2.322	3.120
4	0.580	1.005	1.453	2.507	3.016
5+	0.997	1.170	1.453	2.622	3.107

Source: H-GAC

Table 4.7
Non-Home-Based Work-Based Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.303	0.384	0.486	0.587	0.587
2	0.567	0.815	0.906	0.920	0.920
3	0.939	1.056	1.209	1.377	1.377
4	1.141	1.296	1.511	1.569	1.569
5+	1.263	1.385	1.515	1.840	1.840

Source: H-GAC

Table 4.8
Non-Home Based Other Person Trip Rates

Household Size	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
1	0.725	1.057	1.247	1.574	2.017
2	1.034	1.157	1.415	1.827	2.787
3	1.071	1.283	1.686	2.356	3.183
4	1.157	1.399	1.915	3.038	3.579
5+	1.242	1.399	1.773	2.889	3.420

Source: H-GAC

4.2.2 Trip Attraction

Trip attraction rates have been developed based on the 1995 H-GAC workplace survey, the 1995 H-GAC Commercial Vehicle Survey and the 1995 External Station Survey. The attractions rates are stratified by area type and employment category. The rates also include a stratification for households so as to allow for the estimation of trip attractions to households. Additionally, productions for non-home-based work-based trips are estimated based on area type and employment. Table 4.9 through 4.19 present the track-1 trip attraction rates. Attraction rates are not presented for the HBNW-Airport trip purpose as attractions were estimated as part of the special generator trip attraction estimation process.

Table 4.9
Home-Based Work Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0655	0.7442	1.3589	1.2726	1.3923	1.3481	1.2187	1.2673	0.8151
2	0.0709	0.7765	1.5314	1.3481	1.3864	1.3589	1.2187	1.2626	0.8121
3	0.0989	0.9334	1.5314	1.3481	1.3747	1.3481	1.2079	1.3489	0.8676
4	0.1116	0.8951	1.5314	1.3697	1.3747	1.6501	1.4236	1.3489	0.8676
5	0.1117	1.0902	1.7148	1.5167	1.6017	1.9521	1.6294	1.6665	1.0718

Table 4.10
Home Based Non-Work to Education-1 Person Trip Attraction Rates
(Grades 12 and under)

HBNW-ED1 Zonal Attractions = 8.8986 (Zonal Education-1 employment)

Table 4.11
Home Based Non-Work to Education-1 on School Bus Person Trip Attraction Rates
(Grades 12 and under)

HBNW-ED1 SB Zonal Attractions = 2.68 (Zonal Education-1 employment)

Table 4.12
Home-Based Non-Work to Retail Person Trip Attraction Rates

Area Type	Retail
1	2.1555
2	3.2956
3	5.9876
4	8.191
5	10.2891

Table 4.13
Home Based Non-Work Other Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	Enroll A	Enroll B
1	0.5171	0	0.3657	0.1483	1.2554	1.7793	0.744	0.4785
2	0.6037	0	0.4646	0.1384	1.3048	1.8188	0.744	0.4785
3	0.8332	0	0.7315	0.1384	1.4185	1.9869	0.744	0.4785
4	0.9651	0	0.9885	0.1384	1.5322	2.1451	0.744	0.4785
5	1.0642	0	1.1763	0.1384	1.6854	2.2933	0.744	0.4785

Table 4.14
Non Home-Based Work-Based Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B

1	0.0534	0.2922	1.0688	0.4258	0.334	0.5928	0.6429	0.6847	0.4404
2	0.1013	0.2922	1.0521	0.4425	0.4342	0.6346	0.6429	0.6847	0.4404
3	0.1491	1.002	0.7932	0.1002	0.5344	0.5845	0.6492	0.9936	0.6391
4	0.1478	1.1272	0.7431	0.0835	0.5511	0.5761	0.6555	1.0354	0.6659
5	0.1465	1.169	0.3006	0.0751	0.496	0.4897	0.6555	1.0437	0.6713

Table 4.15

Non Home-Based Other Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.2123	1.4264	0.1783	0.1426	0.7608	0.7132	1.6998	1.4145	0.9098
2	0.216	1.4959	0.2659	0.1219	0.7313	0.6538	1.6289	1.374	0.8837
3	0.3343	2.8512	0.4424	0.1229	0.8111	0.7374	1.9295	1.5362	0.988
4	0.3344	3.6265	0.4533	0.1133	0.957	0.7177	2.0399	1.5866	1.0204
5	0.3344	3.1442	0.3917	0.0783	0.8268	0.5483	1.7625	1.3708	0.8816

Table 4.16

Truck Vehicle Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.1081	0.2155	0.1648	0.2282	0.0887	0.0507	0.2789	0.1141	0.0734
2	0.1179	0.2155	0.1648	0.2409	0.0887	0.038	0.3043	0.1141	0.0734
3	0.1646	0.2155	0.2789	0.2916	0.0887	0.038	0.3043	0.1268	0.0815
4	0.186	0.2282	0.393	0.355	0.0887	0.0254	0.3043	0.1268	0.0815
5	0.186	0.2409	0.393	0.4184	0.0887	0.0254	0.3043	0.1268	0.0815

Table 4.17

Taxi Vehicle Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0063	0.0342	0.0063	0.0038	0.0342	0.0228	0.0228	0.0038	0.0024
2	0.0063	0.0342	0.0063	0.0038	0.0342	0.0228	0.0228	0.0038	0.0024
3	0.0063	0.0342	0.0063	0.0038	0.0342	0.0228	0.0228	0.0038	0.0024
4	0.0048	0.0257	0.0048	0.0029	0.0257	0.0171	0.0171	0.0029	0.0018
5	0.0032	0.0171	0.0032	0.0019	0.0171	0.0114	0.0114	0.0019	0.0012

Table 4.18

External-Local Auto Vehicle Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0139	0.0948	0.0692	0.0324	0.0614	0.0707	0.1333	0.118	0.0759
2	0.0154	0.0985	0.0731	0.0316	0.0621	0.0687	0.1266	0.1151	0.074
3	0.0236	0.1909	0.0769	0.0236	0.0701	0.0723	0.1449	0.1342	0.0863
4	0.0239	0.2355	0.0786	0.024	0.0784	0.0741	0.1507	0.1381	0.0888
5	0.0235	0.209	0.0607	0.0199	0.0682	0.0616	0.132	0.1227	0.0789

Table 4.19

External-Local Truck Vehicle Trip Attraction Rates

Area Type	Household	Retail	Office	Industria	Govt.	Medical	ED-1	ED-2A	ED-2B

	s			l					
1	0.00732	0.0146	0.01116	0.01545	0.00601	0.00343	0.01889	0.00773	0.00497
2	0.00798	0.0146	0.01116	0.01631	0.00601	0.00258	0.02061	0.00773	0.00497
3	0.01114	0.0146	0.01889	0.01975	0.00601	0.00258	0.02061	0.00859	0.00552
4	0.0126	0.01545	0.02662	0.02404	0.00601	0.00172	0.02061	0.00859	0.00552
5	0.0126	0.01631	0.02662	0.02833	0.00601	0.00172	0.02061	0.00859	0.00552

4.2.3 Trip Generation Results

Table 4.20 summarizes the trip generation estimates by trip purpose.

Table 4.20
Regional Trip Estimates by Purpose

Purpose	2002 Trips	Proportion of Total
Home-Based Work Person Trips	3,097,514	17.0
Home-Based Non-Work Educational-1	2,144,192	11.8
Home-Based Non-Work Educational-School Bus	616,667	3.4
Home-Based Non-Work Retail	3,230,065	17.7
Home-Based Non-Work Airport	53,752	0.3
Home-Based Non-Work Other	2,917,352	16.0
Non-Home-Based Work-Based	1,908,548	10.5
Non-Home-Based Other	3,107,703	17.1
Truck	792,383	4.4
Taxi	41,355	0.2
External-Local Auto	252,041	1.4
External-Local Truck	43,814	0.2

Source: H-GAC Model Application Results

4.3 Trip Distribution

The trip distribution models are applied at the detailed TAZ level. These models link or connect trip ends estimated in the trip generation model, determining trip interchanges between each pair of zones. In addition to estimates of the magnitude of activity in each TAZ, the models consider the effects of impedance and accessibility on destination choice. The trip distribution models receive direct feedback from trip assignment, a lower model component.

4.3.1 Person Trip Table Development

The Disaggregate Trip Distribution Model, or Atomistic Model, is used for trip distribution modeling in the Houston-Galveston TMA. This model is used to produce 13 trip tables for the HBW, HBNW-ED1, HBNW-ED1-BUS, HBNW-RETAIL, HBNW-OTHER, NHB-Work-Based, NHB-Other, Truck, Taxi, Extl-Auto, Extl-Truck purposes. A modified version of the Atomistic model is used to produce the various external-local vehicle trip tables. Attractions for the external-local trip purposes as well as the origins and destinations for the external-through purposes are based upon patterns derived from 1995 H-GAC External survey and grown to match year 2002 traffic volumes at the external stations. The underlying assumption in the Atomistic model is that trips occur between small parcels of land (atoms) rather than the defined zone structure; thus by dividing existing zones into atoms a more realistic interchange of intrazonal trips and short (less than five minutes) trips among adjacent zones is defined. In application, a gravity model analogy determines the number of trip interchanges between atoms and subsequently sums the trips to derive both intrazonal trips and zonal interchange volumes. The basic atomistic model formulation is:

$$T_{ij} = \frac{\sum_{v=1}^{M_i}\sum_{q=1}^{M_j} p_{iv} a_{jq} F_{dvq} K_{Sij}}{\sum_{x=1}^{N}\sum_{n=1}^{M_j}\sum_{m=1}^{M_x} p_{in} a_{xm} F_{dnm} K_{Six}} P_i$$

where:

T_{ij} = trips produce in zone I and attracted to zone j

P_{iv} = trips produced by atom v of zone I

P_i = total trips produce in zone I such that:

$$P_i = \sum_{m=1}^{M_i} p_{im}$$

a= relative attraction factor atom q of zone j

A= relative attraction factor for zone j such that:

$$A_j = \sum_{m=1}^{M_j} a_{jm}$$

F= relative trip length factor for estimated separation between atom pair vq

K= bias factor for sector pair containing zones I and j

N= number of zones

My= number of atoms in zone y

In addition to the zonal trip productions and attractions produced in the trip generation process, the trip distribution model requires the zone-to-zone travel times for the estimated minimum time paths on the highway network with 24-hour speeds. The model also requires:

- estimated zonal radii values
- a set of F-factors defining trip length frequency distributions by purpose
- any necessary bias factors (K-factors) by trip purpose

Since the Atomistic Model uses a gravity model analogy that considers travel opportunities within a zone to be spatially distributed rather than concentrated at a single theoretical point (the zone centroid), the spatial dimension of zones is represented by 400 atoms with zonal productions and attractions uniformly distributed among all 400 atoms. The model requires that the distance from the center of a zone to the perimeter be defined in minutes - a zonal radii value. These radii values in conjunction with skimmed travel times determine the spatial distribution of atom pairs for all zonal pairs.

The F-factors used in the 2002 validation were the same set that were developed as part of the 1995 calibration of the Track-1 model set. No changes to F-factors were made as part of the 2002 validation. The calibrated F-factors by purpose are shown in Table 4.21 and 4.22.

K-factors historically, have been used to improve model performance in addressing two natural barriers within the Houston-Galveston TMA: the Houston Ship Channel and the separation between Galveston Island and the mainland. These physical barrier K-factors are included in the 1990 model for both work and non-work trip purposes.
Distinct socio-economic and land use characteristics that require introduction of K-factors are the under-representation of both HBW attractions to the Houston CBD and intra-county HBW trips for the surrounding seven counties. In addition to the CBD, three other major activity centers, (Greenway area, Galleria-Post Oak, and Texas Medical Center) also required K-factors. In the current 1990 model, the original 1985 model K-factors have been retained except in Brazoria County. Additional K-factors refinements were subsequently made for Brazoria County in conjunction with a county roadway planning effort.

Table 4.21
Calibrated F-Factors by Trip Purpose

Time (minutes)	Friction Factors					
	HBW	HBNW-ED1	HBNW-ED1 BUS	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER
1	176.5904	232.8975	238.1769	382.5660	16.3328	340.2945
2	168.9431	227.6921	227.8394	310.9271	14.7153	273.9615
3	144.2355	183.9028	182.7045	210.1103	13.8283	199.3738
4	125.3720	135.6949	135.0980	141.7443	13.0526	139.9891
5	100.0000	100.2968	100.2740	100.0000	12.0302	100.0000
6	83.1710	77.6543	78.1398	73.9970	10.8453	75.7743
7	74.0616	61.2288	61.9420	56.2216	9.6233	59.7854
8	63.7096	48.0930	49.0673	43.0114	8.6517	47.7548
9	55.9424	38.5362	39.6956	33.8165	7.9107	39.0107
10	48.8709	30.8416	32.0028	26.7066	7.3140	31.7736
11	42.7125	24.4937	25.6053	20.9834	6.6357	26.0139
12	37.6481	19.6206	20.5655	16.6469	5.9567	21.3998
13	33.4305	15.8829	16.6935	13.3173	5.2822	17.7919
14	30.0528	13.0380	13.7712	10.6900	4.6961	14.8856
15	27.1232	10.6969	11.3488	8.6139	4.1806	12.5012
16	24.5648	8.7293	9.3010	6.9688	3.7351	10.5449
17	22.3843	7.0437	7.5642	5.6294	3.3404	8.9579
18	20.3234	5.7307	6.2158	4.5782	2.9318	7.6389
19	18.5033	4.7702	5.2349	3.7760	2.5210	6.5694
20	17.0602	4.0057	4.4633	3.1346	2.2390	5.7358
21	15.8807	3.3462	3.7614	2.6041	2.0117	4.9797
22	14.6209	2.7885	3.1536	2.1581	1.7982	4.3425
23	13.5619	2.3181	2.6521	1.7966	1.5904	3.8209
24	12.5997	1.9212	2.2230	1.5097	1.4104	3.3742
25	11.7905	1.5212	1.8688	1.2643	1.2530	2.9807
26	10.9231	1.1978	1.5517	1.0623	1.1211	2.6378
27	9.9135	0.9347	1.1743	0.8954	1.0185	2.3523
28	8.9905	0.7296	0.8902	0.7571	0.9152	2.1094
29	8.1988	0.5682	0.6720	0.6432	0.8076	1.8829
30	7.5501	0.4424	0.4945	0.5440	0.6761	1.6699
31	7.0097	0.3470	0.3688	0.4572	0.5700	1.4802
32	6.4918	0.2690	0.2699	0.3669	0.5021	1.3103
33	6.0534	0.1974	0.1904	0.2967	0.4385	1.1053
34	5.7258	0.1410	0.1263	0.2410	0.3875	0.9441
35	5.4131	0.1096	0.0900	0.1959	0.3344	0.8051
36	4.9775	0.0867	0.0640	0.1587	0.3083	0.6815
37	4.5864	0.0642	0.0412	0.1293	0.2849	0.5765
38	4.2542	0.0430	0.0202	0.1053	0.2568	0.4950
39	3.9744	0.0326	0.0120	0.0856	0.2183	0.4249
40	3.7327	0.0267	0.0074	0.0707	0.1894	0.3634

Table 4.21
Calibrated F-Factors by Trip Purpose
(continued)

Time (minutes)	Friction Factors					
	HBW	HBNW-ED1	HBNW-ED1 BUS	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER
41	3.4630	0.0222	0.0033	0.0579	0.1658	0.3126
42	3.1896	0.0173	0.0000	0.0472	0.1504	0.2697
43	2.9580	0.0137	0.0000	0.0380	0.1414	0.2321
44	2.7457	0.0099	0.0000	0.0312	0.1292	0.1991
45	2.5881	0.0074	0.0000	0.0256	0.1189	0.1703
46	2.4580	0.0062	0.0000	0.0209	0.1094	0.1457
47	2.4000	0.0047	0.0000	0.0168	0.1008	0.1234
48	2.2946	0.0034	0.0000	0.0134	0.0930	0.1036
49	2.1238	0.0023	0.0000	0.0107	0.0858	0.0883
50	1.8849	0.0012	0.0000	0.0085	0.0792	0.0758
51	1.5703	0.0010	0.0000	0.0067	0.0732	0.0650
52	1.3558	0.0006	0.0000	0.0055	0.0677	0.0553
53	1.2962	0.0004	0.0000	0.0044	0.0626	0.0462
54	1.2619	0.0004	0.0000	0.0034	0.0580	0.0387
55	1.2829	0.0002	0.0000	0.0026	0.0537	0.0319
56	1.2054	0.0002	0.0000	0.0022	0.0498	0.0261
57	1.1343	0.0000	0.0000	0.0016	0.0462	0.0214
58	1.0728	0.0000	0.0000	0.0012	0.0429	0.0183
59	1.0157	0.0000	0.0000	0.0009	0.0399	0.0163
60	0.9491	0.0000	0.0000	0.0007	0.0371	0.0135
61	0.9101	0.0000	0.0000	0.0005	0.0345	0.0109
62	0.8508	0.0000	0.0000	0.0004	0.0322	0.0089
63	0.7907	0.0000	0.0000	0.0004	0.0300	0.0073
64	0.7257	0.0000	0.0000	0.0002	0.0280	0.0060
65	0.6800	0.0000	0.0000	0.0003	0.0261	0.0048
66	0.6120	0.0000	0.0000	0.0002	0.0244	0.0037
67	0.5866	0.0000	0.0000	0.0000	0.0228	0.0028
68	0.5591	0.0000	0.0000	0.0000	0.0213	0.0022
69	0.5341	0.0000	0.0000	0.0000	0.0199	0.0016
70	0.5047	0.0000	0.0000	0.0000	0.0187	0.0012
71	0.4882	0.0000	0.0000	0.0000	0.0175	0.0009
72	0.4653	0.0000	0.0000	0.0000	0.0164	0.0006
73	0.4506	0.0000	0.0000	0.0000	0.0154	0.0003
74	0.4321	0.0000	0.0000	0.0000	0.0145	0.0000
75	0.4072	0.0000	0.0000	0.0000	0.0136	0.0000
76	0.3864	0.0000	0.0000	0.0000	0.0128	0.0000
77	0.3707	0.0000	0.0000	0.0000	0.0121	0.0000
78	0.3535	0.0000	0.0000	0.0000	0.0114	0.0000
79	0.3404	0.0000	0.0000	0.0000	0.0107	0.0000
80	0.3404	0.0000	0.0000	0.0000	0.0101	0.0000

Calibrated F-Factors by Trip Purpose (continued)

Time (minutes)	Friction Factors					
	HBW	HBNW-ED1	HBNW-ED1 BUS	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER
81	0.3374	0.0000	0.0000	0.0000	0.0095	0.0000
82	0.3224	0.0000	0.0000	0.0000	0.0090	0.0000
83	0.3208	0.0000	0.0000	0.0000	0.0085	0.0000
84	0.3033	0.0000	0.0000	0.0000	0.0081	0.0000
85	0.2909	0.0000	0.0000	0.0000	0.0076	0.0000
86	0.2630	0.0000	0.0000	0.0000	0.0072	0.0000
87	0.2398	0.0000	0.0000	0.0000	0.0069	0.0000
88	0.2141	0.0000	0.0000	0.0000	0.0065	0.0000
89	0.2042	0.0000	0.0000	0.0000	0.0062	0.0000
90	0.1802	0.0000	0.0000	0.0000	0.0059	0.0000
91	0.1696	0.0000	0.0000	0.0000	0.0056	0.0000
92	0.1693	0.0000	0.0000	0.0000	0.0053	0.0000
93	0.1850	0.0000	0.0000	0.0000	0.0050	0.0000
94	0.1843	0.0000	0.0000	0.0000	0.0048	0.0000
95	0.1836	0.0000	0.0000	0.0000	0.0046	0.0000
96	0.2052	0.0000	0.0000	0.0000	0.0044	0.0000
97	0.2301	0.0000	0.0000	0.0000	0.0042	0.0000
98	0.2481	0.0000	0.0000	0.0000	0.0040	0.0000
99	0.2407	0.0000	0.0000	0.0000	0.0038	0.0000
100	0.2367	0.0000	0.0000	0.0000	0.0036	0.0000
101	0.2042	0.0000	0.0000	0.0000	0.0035	0.0000
102	0.1799	0.0000	0.0000	0.0000	0.0033	0.0000
103	0.1410	0.0000	0.0000	0.0000	0.0032	0.0000
104	0.1211	0.0000	0.0000	0.0000	0.0031	0.0000
105	0.1028	0.0000	0.0000	0.0000	0.0030	0.0000
106	0.1138	0.0000	0.0000	0.0000	0.0028	0.0000
107	0.0951	0.0000	0.0000	0.0000	0.0027	0.0000
108	0.0862	0.0000	0.0000	0.0000	0.0026	0.0000
109	0.0844	0.0000	0.0000	0.0000	0.0025	0.0000
110	0.0785	0.0000	0.0000	0.0000	0.0024	0.0000
111	0.0634	0.0000	0.0000	0.0000	0.0000	0.0000
112	0.0610	0.0000	0.0000	0.0000	0.0000	0.0000
113	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
114	0.0675	0.0000	0.0000	0.0000	0.0000	0.0000
115	0.0597	0.0000	0.0000	0.0000	0.0000	0.0000
116	0.0539	0.0000	0.0000	0.0000	0.0000	0.0000
117	0.0462	0.0000	0.0000	0.0000	0.0000	0.0000
118	0.0348	0.0000	0.0000	0.0000	0.0000	0.0000
119	0.0332	0.0000	0.0000	0.0000	0.0000	0.0000
120	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.21

Calibrated F-Factors by Trip Purpose (continued)

Time (minutes)	Friction Factors					
	HBW	HBNW-ED1	HBNW-ED1 BUS	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER
121	0.1018	0.0000	0.0000	0.0000	0.0000	0.0000
122	0.1317	0.0000	0.0000	0.0000	0.0000	0.0000
123	0.1400	0.0000	0.0000	0.0000	0.0000	0.0000
124	0.1713	0.0000	0.0000	0.0000	0.0000	0.0000
125	0.1334	0.0000	0.0000	0.0000	0.0000	0.0000
126	0.1039	0.0000	0.0000	0.0000	0.0000	0.0000
127	0.0681	0.0000	0.0000	0.0000	0.0000	0.0000
128	0.0528	0.0000	0.0000	0.0000	0.0000	0.0000
129	0.0128	0.0000	0.0000	0.0000	0.0000	0.0000
130	0.0188	0.0000	0.0000	0.0000	0.0000	0.0000
131	0.0288	0.0000	0.0000	0.0000	0.0000	0.0000
132	0.0428	0.0000	0.0000	0.0000	0.0000	0.0000
133	0.0345	0.0000	0.0000	0.0000	0.0000	0.0000
134	0.0276	0.0000	0.0000	0.0000	0.0000	0.0000
135	0.0187	0.0000	0.0000	0.0000	0.0000	0.0000
136	0.0186	0.0000	0.0000	0.0000	0.0000	0.0000
137	0.0109	0.0000	0.0000	0.0000	0.0000	0.0000
138	0.0164	0.0000	0.0000	0.0000	0.0000	0.0000
139	0.0203	0.0000	0.0000	0.0000	0.0000	0.0000
140	0.0429	0.0000	0.0000	0.0000	0.0000	0.0000
141	0.0217	0.0000	0.0000	0.0000	0.0000	0.0000
142	0.0205	0.0000	0.0000	0.0000	0.0000	0.0000
143	0.0157	0.0000	0.0000	0.0000	0.0000	0.0000
144	0.0088	0.0000	0.0000	0.0000	0.0000	0.0000

Table 4.22
Calibrated F-Factors by Trip Purpose

Time (minutes)	Friction Factors					
	NHB Work-Based	NHB Non-Work-Based	TRUCK	TAXI	EXTL-AUTO	EXTL-TRUCK
1	288.5180	284.8357	405.3027	413.6032	16.3328	16.3678
2	246.7716	250.5586	304.4406	312.5369	14.7153	14.7503
3	191.8620	183.1125	209.0045	212.5358	13.8283	13.8633
4	137.2975	134.9805	140.3472	145.1420	13.0526	13.0876
5	100.1150	100.1073	100.0451	101.6013	12.0302	12.0652
6	76.3926	76.7303	76.7624	76.1739	10.8453	10.8803
7	59.8790	60.3820	61.7441	59.1944	9.6233	9.6583
8	46.3062	47.6235	49.8102	46.2512	8.6517	8.6867
9	37.0137	38.1965	40.9965	36.1293	7.9107	7.9457
10	31.4812	30.8489	34.6751	29.1460	7.3140	7.3490
11	26.1231	24.8957	29.4165	24.0599	6.6357	6.6707
12	21.4075	20.3019	25.0952	19.3293	5.9567	5.9917
13	18.1651	16.8614	21.7133	16.1277	5.2822	5.3172
14	16.1508	13.9904	19.0454	13.8370	4.6961	4.7311
15	14.0690	11.6187	16.7764	11.8933	4.1806	4.2156
16	12.2997	9.7191	14.9710	10.2757	3.7351	3.7701
17	10.7461	8.1229	13.2079	8.1010	3.3404	3.3754
18	9.3300	6.7909	11.8109	7.0461	2.9318	2.9668
19	8.0556	5.7503	10.6279	6.0608	2.5210	2.5560
20	6.9513	4.8872	9.6145	5.2713	2.2390	2.2740
21	6.2511	4.2050	8.8614	4.8372	2.0117	2.0467
22	5.6411	3.6289	8.2923	4.2042	1.7982	1.8332
23	5.0673	3.1409	7.6647	3.7348	1.5904	1.6254
24	4.5441	2.7233	7.0556	3.2598	1.4104	1.4454
25	4.0163	2.3458	6.4794	2.8861	1.2530	1.2880
26	3.5432	2.0149	5.9892	2.5824	1.1211	1.1561
27	3.1394	1.7347	5.5225	2.3589	1.0185	1.0535
28	2.7920	1.4997	5.1165	2.0457	0.9152	0.9502
29	2.4669	1.2945	4.7719	1.8111	0.8076	0.8426
30	2.2035	1.1162	4.4519	1.6294	0.6761	0.7111
31	1.9920	0.9658	4.1434	1.5081	0.5700	0.6050
32	1.7866	0.8349	3.8408	1.3568	0.5021	0.5371
33	1.5949	0.6921	3.5722	1.2239	0.4385	0.4735
34	1.4443	0.5811	3.3407	1.0556	0.3875	0.4225
35	1.3261	0.4897	3.1690	1.0019	0.3344	0.3694
36	1.2082	0.4082	3.0165	0.9483	0.3083	0.3433
37	1.0926	0.3345	2.8477	0.8781	0.2849	0.3199
38	0.9883	0.2780	2.6610	0.7471	0.2568	0.2918
39	0.8552	0.2329	2.5119	0.6196	0.2183	0.2533
40	0.7372	0.1932	2.3514	0.5022	0.1894	0.2244

Table 4.22
Calibrated F-Factors by Trip Purpose
(continued)

Time (minutes)	Friction Factors					
	NHB Work-Based	NHB Non-Work-Based	TRUCK	TAXI	EXTL-AUTO	EXTL-TRUCK
41	0.6380	0.1612	2.2003	0.3998	0.1658	0.2008
42	0.5521	0.1344	2.0916	0.3326	0.1504	0.1854
43	0.4790	0.1119	2.0069	0.3107	0.1414	0.1764
44	0.4131	0.0936	1.9038	0.2959	0.1292	0.1642
45	0.3576	0.0772	1.7957	0.2810	0.1189	0.1539
46	0.3167	0.0634	1.7137	0.2611	0.1094	0.1444
47	0.2781	0.0530	1.6353	0.2427	0.1008	0.1358
48	0.2357	0.0440	1.5456	0.2245	0.0930	0.1280
49	0.1987	0.0358	1.4519	0.1771	0.0858	0.1208
50	0.1707	0.0288	1.3738	0.1542	0.0792	0.1142
51	0.1493	0.0236	1.3031	0.1259	0.0732	0.1082
52	0.1296	0.0192	1.2325	0.1032	0.0677	0.1027
53	0.1132	0.0152	1.1629	0.0892	0.0626	0.0976
54	0.0964	0.0121	1.1067	0.0648	0.0580	0.0930
55	0.0804	0.0099	1.0707	0.0628	0.0537	0.0887
56	0.0658	0.0078	0.9885	0.0554	0.0498	0.0848
57	0.0553	0.0063	0.9075	0.0520	0.0462	0.0812
58	0.0475	0.0049	0.8328	0.0516	0.0429	0.0779
59	0.0412	0.0039	0.7696	0.0453	0.0399	0.0749
60	0.0341	0.0032	0.7030	0.0373	0.0371	0.0721
61	0.0281	0.0023	0.6417	0.0247	0.0345	0.0695
62	0.0231	0.0017	0.5919	0.0143	0.0322	0.0672
63	0.0176	0.0011	0.5356	0.0087	0.0300	0.0650
64	0.0141	0.0008	0.4847	0.0077	0.0280	0.0630
65	0.0113	0.0004	0.4486	0.0059	0.0261	0.0611
66	0.0084	0.0002	0.4253	0.0041	0.0244	0.0594
67	0.0061	0.0000	0.4042	0.0032	0.0228	0.0578
68	0.0050	0.0000	0.3686	0.0018	0.0213	0.0563
69	0.0038	0.0000	0.3313	0.0013	0.0199	0.0549
70	0.0029	0.0000	0.2962	0.0008	0.0187	0.0537
71	0.0019	0.0000	0.2748	0.0004	0.0175	0.0525
72	0.0008	0.0000	0.2586	0.0001	0.0164	0.0514
73	0.0000	0.0000	0.2444	0.0000	0.0154	0.0504
74	0.0000	0.0000	0.2233	0.0000	0.0145	0.0495
75	0.0000	0.0000	0.2066	0.0000	0.0136	0.0486
76	0.0000	0.0000	0.1949	0.0000	0.0128	0.0478
77	0.0000	0.0000	0.1764	0.0000	0.0121	0.0471
78	0.0000	0.0000	0.1571	0.0000	0.0114	0.0464
79	0.0000	0.0000	0.1428	0.0000	0.0107	0.0457
80	0.0000	0.0000	0.1350	0.0000	0.0101	0.0451

Table 4.22
Calibrated F-Factors by Trip Purpose
(continued)

Time (minutes)	Friction Factors					
	NHB Work-Based	NHB Non-Work-Based	TRUCK	TAXI	EXTL-AUTO	EXTL-TRUCK
81	0.0000	0.0000	0.1268	0.0000	0.0095	0.0445
82	0.0000	0.0000	0.1240	0.0000	0.0090	0.0440
83	0.0000	0.0000	0.1204	0.0000	0.0085	0.0435
84	0.0000	0.0000	0.1086	0.0000	0.0081	0.0431
85	0.0000	0.0000	0.0929	0.0000	0.0076	0.0426
86	0.0000	0.0000	0.0823	0.0000	0.0072	0.0422
87	0.0000	0.0000	0.0765	0.0000	0.0069	0.0419
88	0.0000	0.0000	0.0701	0.0000	0.0065	0.0415
89	0.0000	0.0000	0.0636	0.0000	0.0062	0.0412
90	0.0000	0.0000	0.0589	0.0000	0.0059	0.0409
91	0.0000	0.0000	0.0555	0.0000	0.0056	0.0406
92	0.0000	0.0000	0.0485	0.0000	0.0053	0.0403
93	0.0000	0.0000	0.0412	0.0000	0.0050	0.0400
94	0.0000	0.0000	0.0344	0.0000	0.0048	0.0398
95	0.0000	0.0000	0.0286	0.0000	0.0046	0.0396
96	0.0000	0.0000	0.0284	0.0000	0.0044	0.0394
97	0.0000	0.0000	0.0233	0.0000	0.0042	0.0392
98	0.0000	0.0000	0.0182	0.0000	0.0040	0.0390
99	0.0000	0.0000	0.0103	0.0000	0.0038	0.0388
100	0.0000	0.0000	0.0061	0.0000	0.0036	0.0386
101	0.0000	0.0000	0.0029	0.0000	0.0035	0.0385
102	0.0000	0.0000	0.0000	0.0000	0.0033	0.0383
103	0.0000	0.0000	0.0000	0.0000	0.0032	0.0382
104	0.0000	0.0000	0.0000	0.0000	0.0031	0.0381
105	0.0000	0.0000	0.0000	0.0000	0.0030	0.0380
106	0.0000	0.0000	0.0000	0.0000	0.0028	0.0378
107	0.0000	0.0000	0.0000	0.0000	0.0027	0.0377
108	0.0000	0.0000	0.0000	0.0000	0.0026	0.0376
109	0.0000	0.0000	0.0000	0.0000	0.0025	0.0375
110	0.0000	0.0000	0.0000	0.0000	0.0024	0.0374
111	0.0000	0.0000	0.0000	0.0000	0.0000	0.0374
112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0373
113	0.0000	0.0000	0.0000	0.0000	0.0000	0.0373
114	0.0000	0.0000	0.0000	0.0000	0.0000	0.0373
115	0.0000	0.0000	0.0000	0.0000	0.0000	0.0372
116	0.0000	0.0000	0.0000	0.0000	0.0000	0.0372
117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0371
118	0.0000	0.0000	0.0000	0.0000	0.0000	0.0371
119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0371
120	0.0000	0.0000	0.0000	0.0000	0.0000	0.0370

Table 4.23

Average Modeled Trip Length by Purpose

Purpose	2002 Average Trip Length
Home-Based Work	21.49
HBNW to Education-1	8.61
HBNW to ED1-Bus	8.72
HBNW to Retail	10.72
HBNW to Airport	29.72
HBNW to Other	13.17
NHB Work-Based	13.02
NHB Other	11.08
Truck	18.78
Taxi	12.56
External-Local Auto	36.79
External-Local Truck	50.75

Source: H-GAC Model Application Results

4.4 Mode Choice

Mode Choice models are mathematical expressions used to estimate travel market modal shares given various competing mode's time and cost characteristics and the urban resident's demographic and socio-economic characteristics. Mode choice models predict traveler's decisions to choose a particular mode of travel and are designed to be an integral link in the travel demand chain, with *possible* direct feedback mechanisms to a number of related model components -- auto ownership, trip generation, and trip distribution

The Houston mode choice model was a nested logit model that addressed eight separate auto and seven different transit modes:

- Drive alone non-toll
- Drive alone toll
- Two person auto non-toll
- Two person auto toll
- Three person auto non-toll
- Three person auto toll
- Four-plus person auto non-toll
- Four-plus person auto toll
- Transit-walk access Local Bus
- Transit-walk access Commuter Bus
- Transit-walk access Express Bus
- Transit-walk access Urban Rail
- Transit-walk access Commuter Rail
- Transit-drive access Park-and-Ride

- Transit-drive access Kiss-and-Ride

Mode usage is calculated for five income levels and three individual trip purposes (Home-Based Work, Home-Based Non-Work, and Non-Home Based). The model was originally estimated based upon 1985 Home-Interview and On-Board Transit Rider Survey data and was calibrated through the mathematical adjustment of bias constants[1] to replicate locally observed travel values. The model has been validated against 1990 and 1995 On-Board survey data.

In the case of public transit, the second level nest distinguishes between walk and drive access (as before), while the third level would now differentiates between local bus transit, express bus, commuter bus, and urban rail for walk access and park-and-ride and kiss-and-ride for drive access. Sufficient aggregate ridership data was available on a regional basis to calibrate a set of model bias constants for each of these sub-modes (except urban rail, which currently does not exist in the region in any form). The existing set of variable coefficients will be used for each of the respective transit submodes. The existing model differentiates (using Boolean coefficients) between the Houston downtown and the three remaining major activity centers. In the enhanced version, each of three major activity centers was individually separated.

The highway mode is sub-divided at the second level of the nest into shared ride and drive alone. Shared ride is further sub-divided into 2-person and 3-person vehicles, and 4+ person autos at the third level. This distinction is necessary as many ramp locations and lane configurations within the region may explicitly distinguish between occupancy levels. The single additional variable added at this level of the nest was an HOV time savings variable (as compared to drive-alone travel time) that was preset at 70 percent of in-vehicle time. The inclusion of this variable is based directly upon recommendations stemming from the Shirley Highway Corridor model estimation.[2] Each of the individual highway sub-modes -- drive-alone, 2-person auto, and 3-person auto, and 4+ person auto -- now include a special path choice nest that differentiates between a toll and non-toll path. Other than a set of modal bias constants, two additional variables are a coefficient on toll cost (stratified by income group) and a coefficient on travel time savings.

As part of a 1995 validation of the mode choice model, it was noted that upon the conversion of the highway person trips by mode (drive alone, 2 person and 3+ person trips) to highway vehicle trips by mode and assignment of those trip tables, regional VMT was less than expected. An analysis of estimated vehicle occupancy by time separation revealed that the trip tables resulting from the mode choice model predicting continually increasing vehicle occupancies by separation. This result was counter to survey observed vehicle occupancy data for separations longer than 30 minutes. This finding led to the modification of Home-Base Non-Work and Non-Home-Based models is two ways.

First, the way in which auto operating costs were handled was modified. The models were modified to allow the user to specify as to whether auto-operating cost were shared among auto occupants or not. It was observed in survey data that most multi-person (2 or more persons in vehicle) home-based non-work and non-home-based trips are made by persons from the same household. In that sense, auto operating costs are not really a shared-cost as it might be in a shared ride work trip made by persons from two different households.

The second modification was to add an additional household size variable to the model. In this way, the model would be sensitive to the size of a household in determining the probability of a

[1] Bias Constants are computed by mode, trip purpose, and income level.

[2] "Review of the Shirley Highway Corridor Mode Choice Analysis", COMSIS Corporation, October, 1990

multi-occupant trip. In the case of a 2-person household, the probability for a 3 or more occupant home-based non-work or non-home-based trip is much lower that for a 3 or more person household given that many of these trips are made by members of the same household.

Subsequent to the validation of the mode choice model to the year 1995, a commuter rail subnest was added to the transit walk-access portion of the model and the drive-access nest was modified to consider commuter rail as part of the park-and-ride and kiss-and-ride alternatives. This enhancement was made to develop forecasts of commuter rail demand in support of a commuter rail planning study.

A graphical depiction of the nested logit model structure for each trip purpose is displayed in Figure 4-2. Lower level nests are defined in the diagram for each of the primary modes - auto and public transit.

The complete set of coefficient values for the Home-Based Work nested logit model is shown in Table 4.24. The Home-Based Non-Work and Non-Home Based values are presented in Tables 4.25 and 4.26 respectively.

Figure 4-2
H-GAC Regional Mode Choice Model - Nested Logit Model Structure

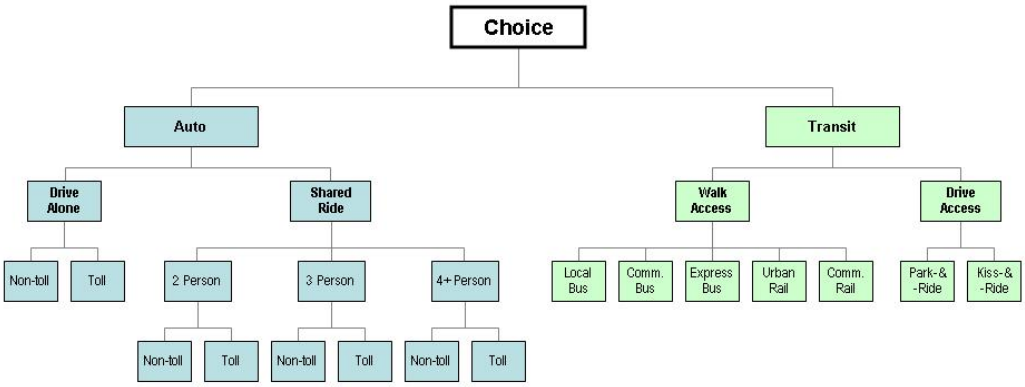


Table 4.24
Coefficient Values for Home-Based Work Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.02203	All modes
1 Wait less than 4.5 minutes	-0.05680	Transit
1 Wait over 4.5 minutes	-0.02203	Transit
Walk	-0.05680	Transit
Transfer time	-0.05680	Transit
Number of transfers	-0.08810	Transit
Transit fare (all)	-0.00614	Transit
Drive to transit time	-0.05680	Transit
Parking cost (all)	-0.01540	Highway
Highway Operating Cost (all)	-0.00614	Highway
Tolls (income group)	-0.00819 -0.00717 -0.00614 -0.00512 -0.00410	Highway
HOV/Toll Time Savings	+0.01542	Highway
Residential Density Indicator	+0.13947	Transit (Walk)
Nesting Coefficients		
Between transit and access	0.75000	Transit
Between access and path	0.60000	Transit
Between single and drive group	0.75000	Highway
Between group and 2/4+	0.60000	Highway
Between 2/4+ and toll/free	0.45000	Highway
Between drive and toll/free	0.45000	Highway

Table 4.25
Coefficient Values for Home-Based Non-Work Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.01727	All modes
1st Wait time	-0.03454	Transit
Walk	-0.02591	Transit
Transfer time	-0.04318	Transit
Transit fare (all)	-0.00592	Transit
Drive to transit time	-0.02591	Transit
Parking cost (all)	-0.01479	Highway
Highway Operating Cost (all)	-0.00592	Highway
Tolls (income group)	-0.01093 -0.00957 -0.00820 -0.00683 -0.00547	Highway
HOV/Toll Time savings	+0.01270	Highway
Household Size 2 Person 3 Person 4+ Person	 +0.07427 +0.44870 +0.75530	 Highway
Residential Density Indicator	+0.07767	Transit (Walk)
Nesting Coefficients		
Between transit and access	0.75000	Transit
Between access and path	0.60000	Transit
Between single and drive group	0.75000	Highway
Between group and 2/4+	0.60000	Highway
Between 2/4+ and toll/free	0.45000	Highway
Between drive and toll/free	0.45000	Highway

Table 4.26
Coefficient Values for Non-Home Based Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.02370	All modes
1st Wait time	-0.04740	Transit
Walk	-0.03555	Transit
Transfer time	-0.03593	Transit
Transit fare (all)	-0.00562	Transit
Drive to transit time	-0.03555	Transit
Parking cost (all)	-0.01404	Highway
Highway Operating Cost (all)	-0.00562	Highway
Tolls (all)	-0.00562	Highway
HOV/Toll time savings	+0.01660	Highway
Nesting Coefficients		
Between transit and access	0.75000	Transit
Between access and path	0.60000	Transit
Between single and drive group	0.75000	Highway
Between group and 2/4+	0.60000	Highway
Between 2/4+ and toll/free	0.45000	Highway
Between drive and toll/free	0.45000	Highway

4.4.4 Calibration of Modal Bias Constants

A key element in the overall mode choice model development process is to insure that the resulting models are able to accurately simulate travel behavior characteristics and patterns within the Houston region.

It is essential that the mode choice model set be able to estimate observed modal trips within a reasonable degree of accuracy. The models were applied at the aggregate (zone) level and the mode specific constants were adjusted to match observed 1995 control values. Applying the models at the aggregate level utilizes the full set of network based travel times and costs, zonal level socio-economic and other related data (i.e., parking costs) and the input trip distribution model person trip tables. In this manner, the models are applied as they would be in forecasting future year trips. Tables 4.27-4.29 summarize the final set of bias constant values for each trip purpose.

Table 4.27
Modal Bias Constants - Home Based Work Mode Choice Model

	Income Level				
Constant	**1**	**2**	**3**	**4**	**5**
Drive Alone - Toll	4.002	3.277	2.512	2.203	1.705
2 Person - Toll	5.190	4.057	3.146	2.337	1.910
3 Person - Toll	5.664	4.723	4.116	4.053	3.829
4+ Person - Toll	6.353	5.454	4.925	4.776	4.466
3 Person Auto	-2.243	-2.329	-2.660	-2.758	-3.149
4+ Person Auto	-3.103	-3.347	-3.938	-4.193	-4.450
Shared Ride	-1.937	-2.072	-2.265	-2.466	-2.786
Auto	0.352	0.813	1.502	2.292	2.497
Local Bus	0.513	-0.228	-0.998	-2.362	-5.163
Commuter Bus	-2.687	-4.192	-2.809	-3.732	-3.175
Express Bus	-1.676	-2.362	-2.121	-2.543	-3.980
Park-and-Ride	-2.332	-1.404	-0.458	-0.103	-0.207
Drive Access	-2.334	-2.019	--1.258	-0.955	--1.099

Table 4.28
Modal Bias Constants - Home Based Non Work Mode Choice Model

	Income Level				
Constant	**1**	**2**	**3**	**4**	**5**
Drive Alone - Toll	2.466	3.223	3.717	4.234	5.257
2 Person - Toll	1.029	1.646	2.109	2.319	2.873
3 Person - Toll	1.873	2.619	3.008	3.440	4.221
4+ Person - Toll	2.179	2.972	3.452	3.908	4.700
3 Person Auto	-2.908	-2.989	-2.989	-3.073	-3.188
4+ Person Auto	-5.149	-5.120	-5.120	-5.177	-5.280
Shared Ride	-0.845	-0.914	-0.914	-0.953	-0.991
Auto	1.578	2.429	3.055	4.214	5.918
Commuter Bus	-2.341	-2.699	0.291	-2.141	2.355
Express Bus	-1.159	-1.175	-1.100	-1.632	0.102
Park-and-Ride	0.122	-0.383	1.647	0.692	1.566
Drive Access	-3.417	-4.089	-4.089	-3.165	-2.873

Table 4.29
Modal Bias Constants - Non Home Based Mode Choice Model

Constant	Value
Drive Alone – Toll	5.056
2 Person – Toll	1.761
3 Person – Toll	2.475
4+ Person – Toll	1.822
3 Person Auto	-1.246
4+ Person Auto	-1.519
Shared Ride	-1.649
Auto	2.477
Commuter Bus	-1.296
Express Bus	n/a
Park-and-Ride	1.807
Drive Access	-3.813

4.5 Commercial Vehicles

In the Track-1 models, commercial vehicle trips include truck and taxi trips. Trips for each of these purposes are separately estimated. Truck and taxi vehicle trips were estimated based on trip attraction rates developed from the 1995 H-GAC Commercial Vehicle survey and trip productions are scaled to match trip attractions. These trips are maintained as a separate class of trip in the auto assignment. Highway travel times represent the purpose impedance.

4.6 External Travel

External trips are categorized into two general categories: external local (external-internal travel) and external through (external-external travel). Within these categories, truck and auto trips have been separated, resulting in four different trip purposes: external-local auto, external-local truck, external-through auto and external-through truck. External-local auto and truck productions are estimated based on the year 2002 counted volume at the external station and the shares of external-local auto and truck as estimated from the H-GAC 1995 External-station survey. External-local attractions are estimated based upon the household survey. External-local attractions are scaled to match external-local productions.

The trip distribution model employs the gravity model form in conjunction with a specified trip length frequency curve. External through trip matrices are derived by frataring the 1995 External Survey based external-through trip tables to match estimated year 2002 external-through trip ends. The year 2002 estimated external through trip ends are based upon the external-through trip share as estimated at each station based upon the 1995 External Survey.

4.7 Trip Assignment

4.7.1 Highway Trip Assignment Methodology

Using the mode choice model, person trips classified by trip purpose are separated into automobile and transit trips and auto person trips are converted to vehicle trips based on vehicle occupancy factors. These vehicle trip tables are summed and converted to origin-destination format and assigned to the appropriate highway network (base year or forecast year). This is a 24-hour capacity restraint assignment performed at the TAZ level. Multiple iterations of the capacity restraint model precede computation of the final assignment results. The model adjusts link impedance between iterations, based on each link's assigned V/C ratio. The weighted average of the assigned volumes from the preceding iterations is used to calculate the V/C ratio. The impedance adjustment function used in this model is based on the FHWA impedance adjustment function. This function assumes impedance is based on a "zero-volume" link speed. However, since traditional coding of Texas highway networks used a 24-hour speed rather than a zero-volume speed, a modified version of the FHWA impedance adjustment function was developed, which is represented by the following formula:

$$I_{n+1} = \left(0.92 + 0.15\left(v/c\right)^4\right) \times I_0$$

Where: I_0 = initial impedance using 24-hour input speed
I_{n+1} = link impedance for iteration n + 1
v = weighted average link volume from iterations 1 to n
c = link capacity

The constraint is applied to limit the magnitude of the impedance adjustment, the maximum of which varies by iteration. After the initial assignment, the maximum impedance factor is two (essentially reducing the 24-hour speed by one-half) and is increased by one for each of the subsequent iterations. The final assignment results are computed following the six iterations, using a weighted average of the link volumes from those iterations. The iteration weights specified for the 1990 base year assignment are determined by an equilibrium capacity restraint process, where each trip is assigned the path with the shortest travel time until equilibrium is achieved.

4.7.2 Comparison to 2002 Counted Volumes

In the 1995 network, there are 20,603 highway links (one-way links) excluding centroid connectors. Of the 20,603, there are 18,535 with count based volume estimates. To demonstrate the validity of the models, comparison of the assigned versus counted VMT is normally summarized to demonstrate the capabilities of the models in matching estimated 1995 base year conditions. As may be noted, nearly half of the freeway and tollway links have counted volume estimates. Over 90% of the arterial and collector links have counted volume estimates.

Table 4.30 summarizes the total assigned VMT on all 20,603 links by 5 roadway types. The assigned VMT on the 18,535 links with counted volumes are also summarized by roadway type. The assigned VMT as a percentage of the counted VMT was computed and is summarized for each of the roadway types. As may be observed, the assigned VMT on freeways, principal arterials and minor arterials are within 3% of the counted VMT estimates. Tollways and collectors VMT are within approximately 9% of the counted VMT estimate.

Table 4.31 summarizes the total assigned VMT on all 20,603 links by 5 area types. The assigned VMT on the 18,535 links with counted volumes are also summarized by area type. The assigned VMT as a percentage of the counted VMT was computed and is summarized for each of the area types. While the CBD Assigned VMT is approximately 85% of counted VMT, this is not unusual for CBD's and is considered within acceptable limits. The assigned and counted VMT in the other area types compare very favorably.

Table 4.32 summarizes the total assigned VMT on all 20,603 links by the 8 counties in the region. The assigned VMT on the 18,535 links with counted volumes are also summarized by county. The assigned VMT as a percentage of the counted VMT was computed and is summarized for each of the counties. The assigned VMT in seven of the eight counties are within 10 % of the counted VMT. Brazoria County's VMT is 86% of the counted which was considered acceptable.

Overall the comparisons of the assigned and counted VMT were considered acceptable and reasonably demonstrate that the models reasonably replace the observed conditions for 1995.

Table 4.30
2002 VMT by Roadway Type

Roadway Type	Number of links	Total Assigned VMT (all links)	Number of Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
Freeway	2,460	47,423,655	1,534	32,691,025	101.3%
Tollway	220	5,946,907	172	4,859,113	104.2%
Prin. Arterial	4,623	18,954,816	1,863	9,401,866	100.4%
Other Arterial	12,171	33,524,268	6,686	20,280,847	103.9%
Collectors	8,082	12,187,532	4,061	5,539,848	102.3%
All Types	27,556	118,037,178	14,316	72,772,699	102.2%

Table 4.31
2002 VMT by Area Type

Area Type	Number of links	Total Assigned VMT (all links)	Number of Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
CBD	799	611,934	117	126,267	90.7%
Urban	4,741	19,045,953	2,377	11,201,853	101.9%
Urban Fringe	10,688	52,963,475	6,081	35,237,639	101.6%
Suburban	6,772	28,238,038	3,420	16,824,054	100.2%
Rural	4,556	17,177,778	2,321	9,336,885	109.0%
All Areas	27,556	118,037,178	14,316	72,726,699	102.2%

Table 4.32
1995 VMT by County

County	Number of links	Total Assigned VMT (all links)	Number of Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
Brazoria	2,109	5,154,406	921	2,324,604	99.4%
Chambers	482	2,310,946	247	1,325,260	101.2%
Fort Bend	1,731	6,944,606	973	4,053,165	101.0%
Galveston	1,996	4,337,961	850	2,305,781	88.5%
Harris	18,449	87,614,181	9,811	55,701,124	102.4%
Liberty	606	1,961,019	310	1,023,427	97.8%
Montgomery	1,661	8,069,604	914	4,866,533	103.8%
Waller	522	1,644,455	290	1,126,805	98.7%
All Counties	27,556	118,037,178	14,316	72,726,699	102.2%

5.0 HPMS VMT ADJUSTMENT

5.1 INTRODUCTION

H-GAC has validated its travel models to the year 2002. As part of the validation, there is a need to re-calculate the factor by which travel model VMT is made to be consistent with VMT estimated by the FHWA Highway Performance Monitoring System (HPMS). The H-GAC Regional Travel Models have been validated to observed vehicle miles of travel (VMT) that are estimated based on roughly 14,000 traffic counts. The estimates and forecasts of vehicle miles of travel produced by the model set are used directly in all transportation planning applications conducted by H-GAC and its transportation planning partners. For purposes of air quality conformity analysis of RTPs and TIPs and the development of State Implementations Plans, H-GAC, through consultation with the Texas Department of Transportation (TxDOT), Texas Commission on Environmental Quality (TCEQ), U.S. DOT and EPA has chosen to reconcile its Base Year (2002) model estimated regional VMT against regional 2002 VMT estimated by HPMS. The factor needed to reconcile model estimated VMT to HPMS estimated VMT is used for all air quality conformity analysis and development of SIPs.

5.2 COMPARISON OF ESTIMATED VMT

In order to compare Base Year 2002 estimated regional VMT to HPMS estimated 2002 VMT, an estimate of total model estimated regional VMT is calculated. Model assigned regional network VMT is combined with assigned regional centroid connector VMT and an estimate of travel within each zone (intrazonal VMT). Because the reconciliation is made for estimated non-summer weekday VMT, both VMT estimates (model and HPMS) are made to represent non-summer weekday VMT. The model VMT is produced in its original form as non-summer weekday VMT, as shown. HPMS VMT represent average annual daily travel (AADT) and is adjusted to represent average non-summer weekday travel, based on an adjusted factor developed using TxDOT permanent traffic recorder data.

Model estimated average non-summer weekday travel (ANSWT)
= (Model network VMT) + (Model Centroid Connector VMT) + (Model Intrazonal VMT)
= (117,334,840) + (11,443,779) + (747,712)
= 129,526,331

HPMS estimated average non-summer weekday travel (ANSWT)
= (HPMS AADT) * (AADT to Non-Summer Weekday Travel Adjustment Factor[A])
= (122,832,328) * (1.0558338)
= 129,690,524

A – taken from 2002, 2009 and 2012 Emission Inventory Document, TTI, August 2005

5.3 CALCULATION OF HPMS ADJUSTMENT FACTOR

The factor used to reconcile model estimated regional VMT to HPMS estimated regional VMT is calculated by dividing the HPMS estimated average non-summer weekday VMT as follows:

HPMS Adjustment Factor

= (HPMS estimated ANSWT) / (Model estimated ANSWT)
= (129,690,524) / (129,526,331)
= 1.001267641

5.4 APPLICATION OF HPMS ADJUSTMENT FACTOR

The HPMS adjustment factor is applied to the model estimated time-of-day VMT prior to the estimation of time-of-day speed. In this way, the time-of-day speeds used in the estimation of emissions are based upon HPMS adjusted VMT.