APPENDIX 4

Travel Model Validation

HOUSTON-GALVESTON AREA COUNCIL

REGIONAL TRAVEL MODELS

2012 Model Validation and Documentation Report

August 2014

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Executive Summary

H-GAC has updated and validated the Track-1 trip-based regional travel demand model to the year 2012. The primary motivation for updating the model was to make use of a new source of observed travel data collected between 2007 and 2012. This same set of travel data is being used by H-GAC in the development, calibration and validation of an activity-based model (ABM) for the region. By updating the trip-based model, H-GAC will have increased travel demand analysis flexibility as well as the ability to compare results of the two models; not only for the base year that the models share (2012), but also for any other applications of the models.

The 2012 Track-1 model is structured very much the same as the 2009 Track-1 model with one exception. Toll demand is now estimated in the Track-1 model in the traffic assignment component rather than in the mode choice component. The motivation for the this change is two fold. First, the practice of estimating toll demand as part of the route choice component (i.e., traffic assignment) has become increasingly common. Second, one change was due to a desire to create consistency among the Track-1 model and the new ABM.

Besides this one structural change to the regional travel models, many of the individual components of the Track-1 model set have been updated with new survey data. Also, some of the model component application procedures have been changed as part of this model update. This section of the validation report presents a brief summaryof those aspects of the model components and procedures that have been changed.

Full documentation of the 2012 Track-1 model is presented starting in Chapter 1 of this document. This full documentation contains more details and presents model results.

Traffic Analysis Zones (TAZs)

The TAZ structure of the Track-1 travel models was updated to a more detailed TAZ structure throughout the 8-county. This updated TAZ structure is designed to reflect increased development in the suburban portions of region and re-development in the urban portions of the region.

Demographics

The TAZ demographics of the Track-1 model were updated to represent the year 2012. Estimates of TAZ-level cross-tabulations of households by size, income and workers per household were developed using H-GAC's population synthesizer. The estimates were controlled to 2010 Census SF1 and 5-year (2006-2010) American Community Survey (ACS) household size, income and worker distributions. Employment estimates by employment type and TAZ for the year 2012 were developed from a variety of sources of business data as well as local appraisal district building data.

Area Type

TAZ area type was updated to reflect the 2012 demographic density based on the updated 2012 TAZ demographics.

Trip Generation

Trip Rates

The trip production rates of the previous Track-1 model have been replaced with trip rates derived from the 2007-2009 regional household survey. The production rates have been enhanced to include a third dimension, workers per household, in addition to household size and household income. In this way, trip demand is sensitive to differences in the number of workers in a household, be that with respect to the base year 2012 or in application of the models to forecasted number of workers per household. While the trip attraction rates are dimensioned as they were in the previous Track-1 model, updated rates were developed based on the 2010/2011 regional workplace survey.

Special Generators

Site trip control totals for Bush Intercontinental and Hobby airports were updated using data from the 2010/2011 regional special generator survey.

Non-resident trips

Estimates of trip ends for trips made by non-residents for the coastal portions of the region were updated based on year 2012 estimates of tract-level seasonal housing as well as hotel and seasonal housing vacancy rates.

Truck Trips

Truck trip demand for the 2012 Track-1 model was developed using H-GAC's Cube Cargo-based truck model. The procedures of this model segment truck demand into cargo truck and service truck demand and estimates of both internal and external truck movements in the H-GAC region. As opposed to estimating truck demand based on trip rates, H-GAC's truck model estimates demand for cargo-carrying trucks based on demand for and flow of commodities to, from and through the Houston region.

External travel

External travel demand, both local and through, was updated based on external volume and vehicle classification counts conducted by H-GAC in 2011. The new volume and classification counts were used to create external-local and through trip ends for auto travel and external-through trips for truck travel. External-local truck travel was estimated separately through the Cube Cargo-based truck demand modeling.

Trip Distribution

The source of Track-1 model off-peak highway travel time impedances used in the distribution of the non-work trip purposes was changed for the 2012 model update from average daily impedance to mid-day impedances. The mid-day impedances were based on assignment output volume-to-capacity ratios from a mid-day traffic assignment. Friction factors for all internal trip purposes other than truck trips were re-calibrated as part of the 2012 Track-1 model update so that model-estimated average trip lengths by trip purpose were consistent with 2007-2009 household survey observed average trip length.

Mode Choice

The regional mode choice model was re-calibrated with year 2012 observed modal target values developed from the 2007-2009 regional household survey and a 2012 transit on-board survey. As previously mentioned, the one change in model structure involved the movement of the toll demand estimation procedures from the mode choice model to the assignment model. For this reason the toll sub-nests of the mode choice model were not included in the re-calibration.

Time-of-Day Models

A fifth time-of-day period was added to the time-of-day modeling procedures of the 2012 Track-1 model to acknowledge peak spreading that has occurred in the region, particularly the spreading of the PM peak period. This fifth period, referred to as the 'evening' period is designed to capture the PM peak period spill-over congestion while maintaining the length of the original PM peak period. As a result of the creation of the evening period, the length of the overnight period was reduced

Using data from the 2007-2009 regional household travel survey, time-of-day factors for the five time-of-day periods were developed. As with the prior set of diurnal factors, the updated factors perform two functions. First, to factor the daily demand to the demand for the time period of interest, and second, impart the appropriate directionality of travel for the time period of interest.

Traffic Assignment

As previously mentioned, H-GAC changed the step in which the Track-1 model estimates toll demand. The Track-1 2012 model estimates toll demand via the traffic assignment component rather than the mode choice component. This was accomplished through a generalized-cost (GC) assignment for each of the five time-of-day periods. One of the primary motivations for choosing to move to a generalized-cost assignment is to allow for the use of the same assignment procedures for both the trip-based model and the H-GAC's in-development ABM. The GC assignment method made use of values-of-time that are segmented by trip purpose, income and mode. In this way, toll demand was affected not only by time-of-day, but also by the purpose of the trip and whether the trip is an SOV trip or an HOV trip.

A second change to the traffic assignment procedures involved the replacement of a daily assignment with the sum of time-of-day assignments. H-GAC's travel models have included time-of-day traffic assignment for many years. However, H-GAC also performed daily traffic assignments. As part of the 2012 Track-1 model update, H-GAC used summed time-of-day assignments to represent daily traffic assignment demand.

Feedback

The feedback procedures used in the Track-1 model were updated to evaluate mid-day along with AM peak period assignment and impedance statistics as part of the departure from the creation of daily impedances for trip distribution and the performance of daily traffic assignments. The 2012 Track-1 model update achieved the convergence criteria in three iterations.

Assignment Validation

The results of the time-of-day traffic assignments were summed to represent daily traffic volume on the modeling network. The resulting daily traffic volumes were then compared to the year 2012 daily traffic counts both on the basis of traffic volume and vehicle miles of travel (VMT). The comparison of assigned and counted volumes and VMT are presented in Chapter 4 of the validation document.

Summary

The 2012 Track-1 model set is structured virtually the same as the 2009 Track-1 model set, except for movement of toll demand estimation from the mode choice to the traffic assignment procedure. The trip generation, trip distribution, and mode choice components were updated and calibrated to match a new set of survey data and external count data while the modified traffic assignment procedures were validated against counted daily traffic.

1. 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 update, calibration and validation of the H-GAC trip-based travel model set – referred to as the "Track-1" model set to the Base Year 2012 by H-GAC. The "Track-1" model set that was last validated to the year 2009 has been updated with new survey data, year 2012 demographic data, updated highway and transit network and level-of-service data and validated against year 2012 traffic counts.

1.1. Report Structure

Chapter 2 of the report discusses the development of TAZ, demographic and cost data for the Base Year 2012. 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 modeling components and the efforts in their update as part of the model validation.. The 2012 traffic assignment validation results are also presented 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. TAZs & Demographics

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. Demographic estimates and forecasts for the TMA are developed by H-GAC.

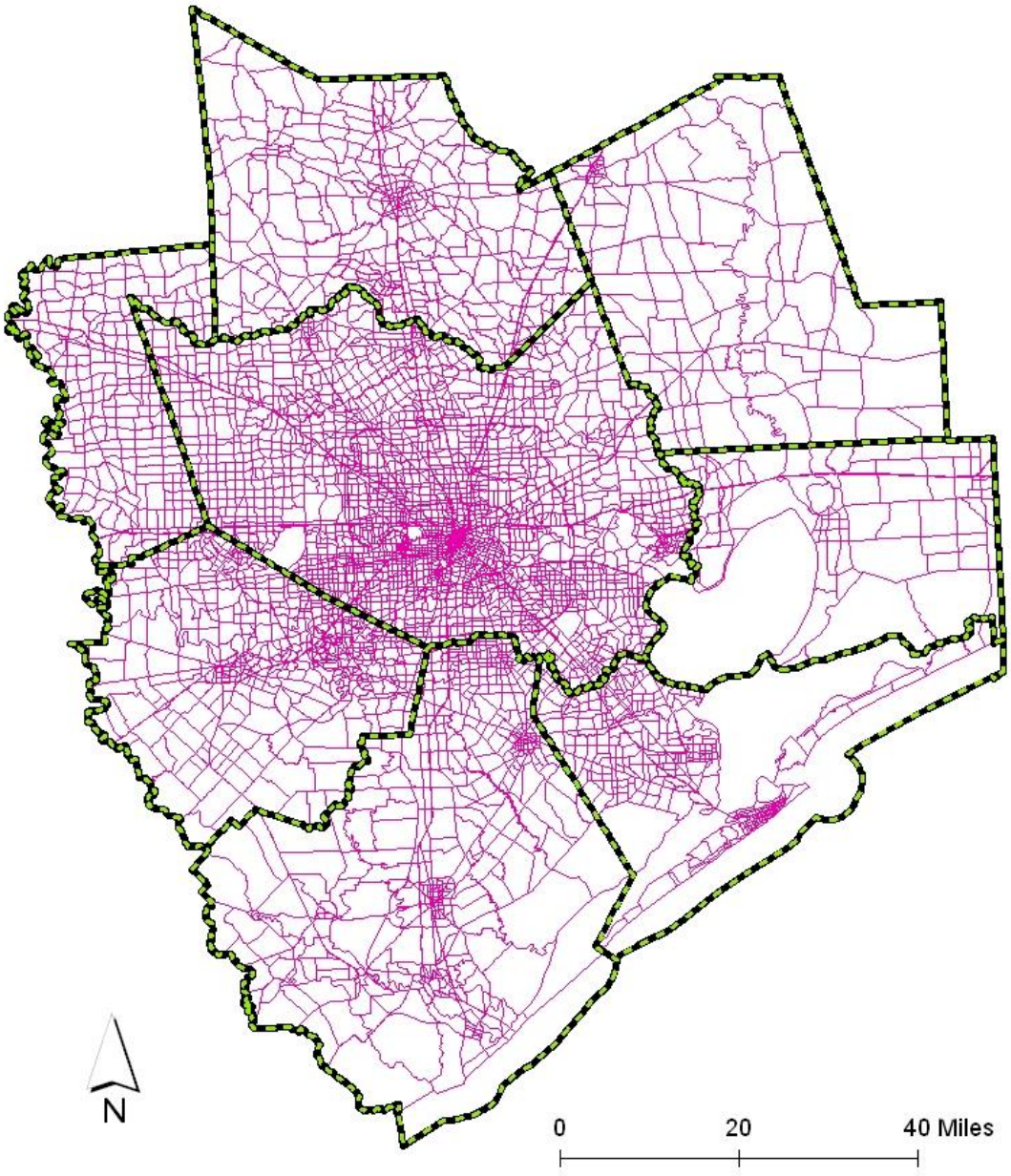
2.1. Zone System Definition

The level of detail of the Traffic Analysis Zone (TAZ) system of the Track-1 model was increased as part of the 2012 Track-1 model update. The 2012 Track-1 model makes use of 5,159 traffic analysis zones (TAZs) to represent the Houston-Galveston TMA. This includes 5,113 internal zones and 46 external stations. Figures 2-1 and 2-2 present the geographic extent of the TMA and the internal TAZ structure that is used in the 2012 Track-1 travel model. Table 2.1 presents a comparison of the previous TAZ and new TAZ structure of the Track-1 model set.

Figure 2-1 H-GAC Transportation Management Area (TMA)

Source: H-GAC

Figure 2-2 H-GAC TAZ Structure



Source: H-GAC

Table 2.1 TAZ By County

COUNTY	# of TAZs	
	2009 TRACK-1	2012 TRACK-1
Harris	1,846	2,868
Brazoria	283	522
Fort Bend	192	548
Waller	58	225
Montgomery	226	333
Liberty	78	126
Chambers	46	94
Galveston	225	397
External Stations	46	46
Region Total	3,000	5,159

2.2. Year 2012 Demographic Estimates

Demographic inputs to the 2012 Track-1 model update and validation were year 2012 household and employment by TAZ. Population and household inputs were developed using H-GAC's population synthesizer and, in the case of households, were controlled to 2010 Census data. Employment for the year 2012 was developed using business and employment data sets along with building data.

2.2.1 Households

H-GAC's population synthesizer uses detailed information on a small sample of the region's population and then uses iterative proportional fitting (IPF) and various simulation techniques to develop the detailed cross-tabulation of households and distributions by household size, household income and workers for each TAZ. Household data creation took place in two phases: the first phase involved creation of population and households by household size while the second phase involved development of household income and worker status of the population.

In phase I, the margins of multi-way (age, sex, age of householder) contingency tables were filled with the block-level 2010 SF1 U.S. Census data and then the cell values of these tables were developed using IPF to match the margins. After all the tables were filled in with the values, the distributions of households and persons was created from the summary tables. The resulting households and persons are called the base year 2012 population. Next, a simulation is ran produce year 2012 population and household by evolving base year 2012 popluation. The simulation simulates immigration, emigration, natural birth and death, and marriage which all impact population and household mix.

In phase II, American Community Survey (ACS) data was used to "impute" worker status for individuals and income for households. Household income was imputed by constructing household income frequency distribution table contingent on age and race of the householder. Next, each householder from the disaggregate data developed in phase I was matched with the income data by county, age, and race. Then, a simulation technique was used to assign a specific income level to each householder. Worker status was imputed using 2006-2010 ACS Public Use Survey Microdata (PUMS). Individuals from phase I were

matched to individuals in PUMS on up to 8 dimensions simultaneously. This method "finds" individuals in PUMS that are similar to phase I individuals in personal and household characteristic and then develops a frequency distribution to impute worker status using the same simulation method used to assign a income.

For purposes of application in the 2012 Track-1 models, the households were assigned to one of five size groups (1- 5+ persons per household), one of three workers per household group (0-2+ workers per household group) and one of five household income groups. The five income groupings used in the 2012 Track-1 models are listed in Table 2.2

Table 2.2 Year 2012 Household Income Groupings

Income Group	Range (2012 $)
1	0 - 22,499
2	22,500 - 39,999
3	40,000 - 64,999
4	65,000 - 99,999
5	100,000+

Table 2.3 presents a summary of the year 2012 households summarized by each of the dimensions by which they are input into the travel model.

Table 2.3 2012 Households By Size, Income & Workers Per Household Dimensions

HOUSEHOLD SIZE	# HHs	HOUSEHOLD INCOME	# HHs	WORKERS PER HH	# HHs
1	503,918	$0 - $22,499	414,345	0	546,039
2	618,724	$22,500 - $39,999	379,424	1	916,710
3	368,056	$40,000 - $64,999	454,437	2+	702,554
4	339,784	$65,000 - $99,999	395,368		
5+	334,821	$100,000+	521,729		
Total	2,165,303	Total	2,165,303	Total	2,165,303

Table 2.4 summarizes households at the county-level for the years 2000 and 2012. Region wide households increased over 32 percent, from 1.64 million in 2000 to nearly 2.17 million in 2012. Relative household growth by county ranged from a low of 8.5 percent in Liberty County to a high of 86.6 percent in Fort Bend County. Not surprisingly, Harris County for over half (55%) of the overall absolute growth in households. Table 2.5 summarizes the household population by county (which excludes group quarters such as prisons). The pattern of growth in household population largely tracks the growth in households, as would be expected.

Table 2.4 County Households for 2000 and 2012

County	Year 2000	Year 2012	Change	% Change
Harris	1,205,516	1,495,610	290,094	24.1%
Brazoria	81,954	112,729	30,775	37.6%
Fort Bend	110,915	206,933	96,018	86.6%
Waller	10,557	14,079	3,522	33.4%
Montgomery	103,297	180,969	77,672	75.2%
Liberty	23,242	25,222	1,980	8.5%
Chambers	9,139	12,624	3,485	38.1%
Galveston	94,782	117,137	22,355	23.6%
Region Total	1,639,402	2,165,303	525,901	32.1%

Source: Trip Generation Data for 2000 and 2012 prepared by H-GAC

Table 2.5 County Household Population for 2000 and 2012

County	Year 2000	Year 2012	Change	% Change
Harris	3,358,444	4,200,326	841,882	25.1%
Brazoria	230,806	314,151	83,345	36.1%
Fort Bend	348,154	616,554	268,400	77.1%
Waller	29,454	39,561	10,107	34.3%
Montgomery	292,077	487,992	195,915	67.1%
Liberty	65,113	70,757	5,644	8.7%
Chambers	25,797	36,133	10,336	40.1%
Galveston	246,002	303,069	57,067	23.2%
Region Total	4,595,847	6,068,543	1,472,696	32.0%

Source: H-GAC

2.2.2 Employment

TAZ employment for the year 2012 was developed from two primary datasets; the first comprised of buildings and the second comprised of businesses. The building data was obtained from county appraisal district data. The business data, which becomes the employment data, came from a variety of sources including the Texas Workforce Commission, InfoUSA, Texas Education Agency, Texas Department of State Health Services, the Houston Business Journal as well as various local government agencies. As the data is derived from multiple sources, it does include some self-employment and other unique employment types that are typically not included in common public employment data sources.

After data from the various data sources was standardized to company name and address, the businesses were geocoded to buildings from the county appraisal district data. Following geocoding, the employment was reviewed at the building level to identify issues with headquarters offices that result in overcrowding of the building. Building overcrowding is addressed through review of secondary data sources for location of branch office and/or adjustment of building employment to a typical value for the building type.

Following clean-up of the employment locations, the six-digit NAICS employment data was converted the employment categories used by the Track-1 travel demand model at the parcel level. The last step in the process was to summarize the parcel level employment to TAZ.

Table 2.6 presents a summary of the year 2012 employment by the employment categories used in the 2012 Track-1 model.

Table 2.6 Year 2012 County Employment by Employment Type

COUNTY	RETAIL	OFFICE	INDUSTRIAL	MEDICAL	EDUCATIONAL (K-12)	EDUCATIONAL (POST SECONDARY)	GOVERNMENT	TOTAL
Harris	628,131	920,339	364,219	250,551	68,819	15,756	80,863	2,354,553
Brazoria	34,597	19,455	14,549	8,792	4,093	760	4,933	87,179
Fort Bend	61,172	42,640	24,227	18,100	9,550	1,000	6,351	163,129
Waller	2,431	3,338	2,656	924	440	1	446	11,351
Montgomery	60,849	44,456	8,177	16,464	6,928	1,794	5,743	144,411
Liberty	4,409	3,430	1,119	2,123	1,501	4	1,728	14,314
Chambers	3,993	1,071	5,830	502	1,065	-	887	13,348
Galveston	40,156	22,012	8,671	11,415	4,230	527	7,063	98,798
Region Total	835,738	1,056,741	429,448	308,871	96,626	19,842	83,448	2,887,083

A comparison of the year 2000 and year 2012 employment for the eight county region, as presented in Table 2.7, shows that employment increased comparably with population growth, 32.5% percent overall. Harris County gained over 550,000 jobs while Montgomery County employment grew more than 70.5% percent (over 59,000 jobs). In addition to the household, population and employment values themselves, the ratio of these variables to each other is frequently used to asses changes to a region's demographic characteristics over time.

Table 2.7 County Employment for Years 2000 and 2012

County	Year 2000	Year 2012	Change	% Change
Brazoria	75,556	87,179	11,623	15.4%
Chambers	7,759	13,348	5,589	72.0%
Fort Bend	96,316	163,129	66,813	69.4%
Galveston	86,469	98,798	12,329	14.3%
Harris	1,802,351	2,354,553	552,202	30.6%
Liberty	15,484	14,314	-1,170	-7.6%
Montgomery	84,719	144,411	59,692	70.5%
Waller	9,611	11,351	1,740	18.1%
Region Total	2,178,265	2,887,083	708,18	32.5%

Source: H-GAC

Table 2.8 presents comparisons among these demographic comparison metrics between the year 2000 and the year 2012.

Table 2.8 Comparative Statistics – County Level —Years 2000 and 2012

County	Year	Person/HH	Pop/Emp	Emp/HH
Harris	2000	2.79	1.86	1.50
	2012	2.81	1.78	1.57
Brazoria	2000	2.82	3.05	0.92
	2012	2.79	3.60	0.77
Fort Bend	2000	3.14	3.61	0.87
	2012	2.98	3.78	0.79
Waller	2000	2.79	3.06	0.91
	2012	2.81	3.49	0.81
Montgomery	2000	2.83	3.45	0.82
	2012	2.70	3.38	0.8.
Liberty	2000	2.80	4.21	0.67
	2012	2.81	4.94	0.57
Chambers	2000	2.82	3.32	0.85
	2012	2.86	2.71	1.06
Galveston	2000	2.60	2.84	0.91
	2012	2.59	3.07	0.84
Region	2000	2.80	2.11	1.33
	2012	2.80	2.10	1.33

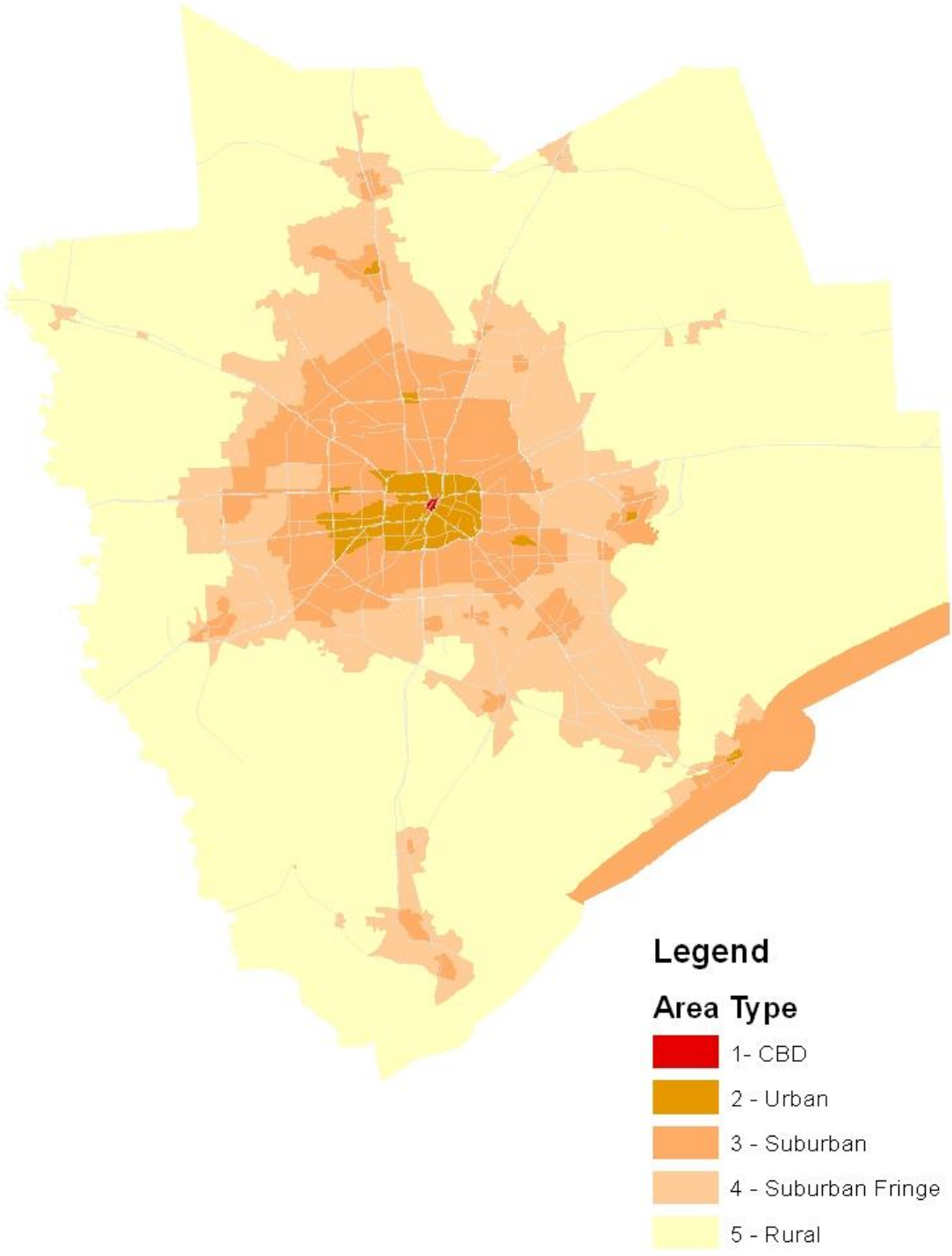
The increase in persons per household in Harris County and thus, the region, reflects the ethnic component of population growth between the year 2000 and the year 2012. The regional population-to-employment and employment-to-household ratios are almost identical between the two years, but these ratios varies for within a county. This reflects that overall both employment and population grows rapidly in similar rate regionwide, but locally these two grow rates could be different.

2.3. Year 2012 Area Types

The TAZ area type was calculated based upon the population and the employment total of the subject TAZ and eight neighboring TAZs. In this way, the area type was not only a function of the TAZs individual demographic density but also reflects characteristics of the surrounding area. Year 2012 area types were calculated using the zonal population and employment estimates along with the regional population/employment ratio.

Following automated calculation of each TAZs area type, the resulting area types were reviewed and further smoothed, as needed. Figure 2-3 presents the final 2012 TAZ area types.

Figure 2-3 Year 2012 TAZ Area Types



3. Highway/Transit Networks & Related Data

3.1. Highway Network Characteristics

Highway supply characteristics that are required by the regional travel model 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 2012 base year highway network includes key operational features for approximately 12,700 center-line miles of roadways in the Houston-Galveston TMA, and consists of more than 24,000 roadway links (one-way for freeway and managed lanes, two-way for arterials and collectors, and excluding centroid connectors). Each link's physical and operating characteristics are described in a link data record. 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 daily and time-of-day weekday traffic count and direction (one-way/two-way) are also carried in the modeling network. Link data items such as facility type classification, daily speed and time-of-day capacity were from this operational-oriiented information. 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.

Table 3.1 Facility 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	Reversible 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	Light Rail
31	Commuter Rail
32	Transfers from rail station
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)
80	Reversible HOT Lane (barrier-separated)
99	Walk to Transit Only Centroid Connector

3.1.1. Link Capacity

The 2012 Track-1 travel models make use of multi-hour time-of-day capacities in the traffic assignment component. The multi-hour capacities are based on hourly capacities which vary by facility type and area type.

The hourly capacities themselves represent level-of-service (LOS) “E” capacities and are based on Highway Capacity Manual (HCM) flow rates. The HCM flow rates were then adjusted, as appropriate for the capacity effects of turns, and in the case of non-freeways, intersection control. Additionally, as the capacities are expressed in terms of vehicles, there is an accounting for the effects of trucks on the flow rate as part of the capacity development. assumed typical to account LOS E.

The hourly capacity per lane was calculated as a function of the hourly saturation flow rate as follows:

$$\frac{CS \times \frac{G}{C} \times \frac{V}{C} \times PHF \times U}{1 + \left(P_t\left(E_t - 1\right)\right)} + LTVP$$

Where: CS = saturation flow rate (2,300 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 (assumed to be 1.0 for freeways);
P_t = percent of trucks;
E_t = truck equivalency factor; and
LTVP = left turn volume in the peak hour and peak direction.

The capacity of a freeway link is simply the hourly per lane capacity times the number of lanes coded on the link. For non-freeway facilities, the lane utilization factor varies based on the number of lanes. For this reason, the capacity of a non-freeway varies slightly among different lane configurations of a link. Freeway and non-freeway hourly capacities are presented in Appendix A.

The process for developing multi-hour capacities which correspond to the time-of-day assignment periods was simply a matter of multiplying the length of the time period by the hourly capacity. In other words, the capacity for the three hour AM peak period is the hourly capacity multiplied by three while the capactity for the four hour PM peak period is the hourly capacity times four. This method of multi-hour capacity development was used with the intended use of the assignment results in mind. As the assignment results, in particular, the resulting volume-to-capacity (V/C) ratios are used in development of inputs for mode choice and for emissions estimation, the (V/C) ratios should represent the average hourly V/C across the time period. For this to be case, the "C" portion of the V/C ratio should be the full capacity for the time period of interest.

3.1.2. Link Speed

Besides time-of-day capacity, each link was populated with a link speed that is used to develop travel time impedances used in the initial round of trip distribution and in the initial iteration of all traffic assignments. For non-centroid connector links, the initial link speed is simply the free-flow (zero-volume) speed, which varies by link type and area type, The initial link speeds for non-centroid links are presented in Appendix A.

Speeds on auto 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 the area type 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 (rural) zone sizes will increase accordingly. Thus, each of the five area types have a unique set of equations for determining centroid connector speeds. A representative table of centroid connector speeds for a distance of one mile would be as shown in Table 3.2. Appendix B presents additional detail on the process used to calculate centroid connector speed.

Table 3.2 Example Centroid Connector Speeds

Area Type	Distance (miles)	Speed (mph)
CBD	0.05	20.0
Urban	0.95	40.0
Suburban	1.20	40.0
Fringe Suburban	1.70	40.0
Rural	1.80	40.0

Source: H-GAC

3.1.3. Link Toll Costs

Toll costs were used in the assignment model as part of the generalized cost path building. The toll costs were placed on the links in the network that represent the locations where the tolls are actually collected. The costs represent the average cost paid among both toll tag and cash patrons. Table 3.3 lists the year 2012 toll costs.

Table 3.3 Year 2012 Toll Costs

Location	Toll Cost
Hardy - North Plaza	$1.35
Hardy - FM 1960 Ramp	$1.00
Hardy - Richey Ramp	$1.00
Hardy - Rankin Ramp	$0.75
Hardy - South Plaza	$1.33
Hardy - Bush IAH Ramp	$1.00
Hardy - Greens Road Ramp	$0.75
Hardy - Aldine Mail Ramp	$1.00
Hardy - Little York Ramp	$1.00
Hardy - Tidwell Ramp	$0.75
Sam Houston North Plaza	$1.33
Sam Houston North - SH 249 Ramp	$1.00
Sam Houston North - North Gessner Ramp	$1.00
Sam Houston North - Fallbrook Ramp	$1.00
Sam Houston Central - West Road Ramp	$0.75
Sam Houston Central Plaza	$1.33
Sam Houston Central - Clay Road Ramp	$1.00
Sam Houston Central - Hammerly Ramp	$0.75
Sam Houston Southwest Plaza	$1.33
Sam Houston Southwest - South Main (90-A)	$0.75
Sam Houston Southwest – Fort Bend Tollway	$0.75
Sam Houston Southwest - West Fuqua	$1.00
Sam Houston Southwest – Almeda	$1.00
Sam Houston South Plaza	$1.33

Sam Houston South – Deerwood	$1.00
Sam Houston South - Briar Forest	$1.00
Sam Houston South – Westheimer	$1.00
Sam Houston South – Bellaire	$0.75
Sam Houston South - Westpark Tollway	$0.50
Sam Houston Southeast Plaza	$1.33
Sam Houston Southeast - Cullen	$0.75
Sam Houston Southeast – Wayside	$1.00
Sam Houston Southeast – Telephone Rd	$1.00
Sam Houston Southeast – Monroe	$0.75
Sam Houston East Plaza	$1.33
Sam Houston East - Fairmont Parkway	$1.00
Sam Houston East - Spencer Highway	$1.00
Sam Houston East - Red Bluff	$0.75
Sam Houston Ship Channel Bridge	$1.58
Sam Houston Northeast – Tidwell	$0.50
Sam Houston Northeast – Garrett	$0.75
Sam Houston Northeast – Winfield	$0.75
Sam Houston Northeast Plaza	$1.33
Sam Houston Northeast – W. Lake Houston Pkwy	$0.75
Sam Houston Northeast – John Ralston	$0.50
Sam Houston Northeast – Wilson	$0.50
Fort Bend Toll Main Plaza	$0.85
Lake Olympia Pkway Ramp	$0.35
McHard Road FM 2234 Ramp	$0.65
Fort Bend Parkway FM 2234 Mainline	$0.40
Fort Bend Parkway Highway 90A Plaza	$1.33
Westpark Toll Peek Mainlane	$0.65
Westpark Toll Grand Mission Mainline	$0.65
Westpark Toll HW6 westbound Ramp	$0.50
Westpark Toll Wilcrest Mainline	$1.30
Westpark Toll Gessner Road Entrance/Exit	$0.35
Westpark Toll Fondren East Exit	$0.50
Westpark Toll Fondren East Entrance	$0.75
Westpark Toll Fondren East Mainline	$1.30
Westpark Toll Fondren West Mainline	$1.30
Westpark Toll Westpark Drive East Ramp	$0.35
Westpark Toll South Post Oak Exit	$0.35
Katy Managed Lanes Wirt Plaza	0.36 – 1.20
Katy Managed Lanes Wilcrest Plaza	0.36 – 1.20
Katy Managed Lanes Eldridge Plaza	0.48 – 1.60
San Luis Pass-Vacek Toll Bridge	$2.00

3.2. 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.

3.2.1. 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. Many local bus routes and the light rail routes run more frequently during peak periods. Similarly, not all routes or subroutes operate during the course of the entire day. Express and Commuter bus routes, in particular, generally operate only during the morning and afternoon peak periods. In order to properly reflect these differences, separate peak and off-peak 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 first determines the best paths between the orign and destination, and then recognizes that several lines of same transit modes as the best path coice 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 models where this recognition ignores some transit routes from irrelavent transit modes.

3.2.2. Transit Modes

Every transit route contains a number identifier for each transit modes. The following transit modes are used:

- 1: local bus
- 2: express bus
- 3: commuter bus
- 4: light rail
- 5: commuter rail

There was no existing commuter rail service in the region in for year 2012. The commuter rail mode is reserved for model forecasting and alternative analysis.

3.2.3. Transit Travel Times

Transit 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. Two basic types of TTFs are included in the model:

I. Simple assumed speed

II. Auto speed multiplied by an auto-to-transit time factor and added by a constant

Type I TTFs are coded with an assumed speed, which is constant across all links. Type 1 TTF are applied on HOV, HOT, access and egrees inside a park-and-ride, and walk links. The speed is 3 miles per hour (mph) for walking, 12 mph inside park-and-ride, 53 mph on HOV link. Type II TTFs apply a multiplicative factor and an additive factor to auto time to relate transit link travel time to the corresponding auto travel time. The general form of Type II TTFs is

$$S_{transit} = C + \alpha \times S_{auto}$$

where S_{auto} is the congested auto travel speed, C is the additive factor, and α is a multiplicative factor. The values of C and α varies by different transit modes and stop/non-stop portion of the routes.

Light rail and commuter rail do not apply the TTF as these modes operate in separate rights-of-way. Therefore, their speeds are minimally impacted by congestion.

The values of C and alpha are presented in Table 3.4.

Table 3.4 Transit Time Function Parameters

Transit Route Type	Additive Factor	Multiplicative Factor	
		Area Type 1	Area Types 2-5
Local Bus Stop	4	0.217	0.447
Local Bus Non-Stop	0	0.625	0.930
Express Bus Stop	4	0.230	0.480
Express Bus Non-Stop	0	0.625	0.930
Commuter Bus Stop	4	0.230	0.540
Commuter Bus Non-Stop	0	0.625	0.930

3.2.4. Waiting Times

Waiting times are the times between the passengers arriving at the transit stop and boarding to transit vehicles. Assuming every passengers arrive the transit stop totally random, their average waiting time should be one half of the bus headway. When the headway exceeds certain theresold, the waiting time should stop increasing and remains constant because passenger could avoid extremely long waiting time.

Passengers also perceive waiting time and in-vehicle time differently. They often perceive the same amount of time waiting longer than then in-vehicle time because they are less comfortable while waiting. Weather, safety, and anxiety waiting for a bus arrival factors which make waiting less comfortable than in a transit vehicle. As a result, passengers perceives waiting time longer than its actual value, The model should use the perceived waiting time in transit path building

and in mode choice to represent that passengers are less comfortable to wait than to be inside a transit vehicle.

There are two kinds of waiting times: initial waiting time and transfer waiting time. Initial waiting time is the waiting time before any transfer – which is the waiting time for the first transit leg. Transfer waiting time is the waiting time between transferring from one transit route to another transit routes.

The model calculates the perceived waiting time as a function of headway. It assumes the actual waiting time is one half of the headway for headway less than two hours, and the actual waiting time remains constant afterwards. Then, the model will factor the actual waiting time with a weighing factor to get the perceived waiting time. The followings are the actual-to-preceived waiting time weight factors:

- First 4.5 minutes of HBW initial waiting times 1.00
- After 4.5 minutes of HBW initial waiting times 2.00
- HBW transfer waiting times 2.58
- HBNW and NHB initial waiting times 2.00
- HBNW and NHB transfer waiting times 2.00

After applying the weighing factors above, the perceived waiting time functions have these forms. The headways and perceive waiting time are as shown in Table 3.5.

Table 3.5 Turning Points of Various Waiting Time vs Headway Functions

Headway	0	1	9	120	180
HBW Initial Wait Time	0	1	9	64.5	64.5
HBW Transfer Wait Time	0	1.29	11.61	154.80	154.80
HBNW NHB Initial Wait Time	0	1	9	120	120
HBNW NHB Transfer Wait Time	0	1	9	120	120

3.2.5. 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 2012 validated model (all times are in minutes):

- Preceived Boarding Penality: 10.0 minutes
- Transfer Penality: 4 minutes
- Local Bus In-vehicle time weight factor(for premium modes pathing): 1.30
- Commuter Rail In-vehicle time weight factor(for peak premium modes pathing): 0.80
- Maximum transfer allowed: 2
- Maximum weight travel time: 300 minutes
- Waiting time weight factor: 1.0
- Auto access time weight factor: 1.0

- Peak walk time weight factor: 2.58
- Off-peak walk time weight factor: 2.0

4. Model Components

4.1. Introduction

The 2012 Track-1 models, with two exceptions, ars structured in the same way as the 2009 Track-1 model. The first exception deals with the estimation of toll demand. The modeling procedures have been modified such that toll demand is estimated in the traffic assignment stage rather than the mode choice stage. The second structural change has to do with commercial vehicle (i.e., truck) travel. Truck travel is estimated by a truck model that functions separately from the 2012 Track-1 model rather than through the trip generation model.

The 2012 Track-1 models represent an update of the trip generation, trip distribution and mode choice models with new travel survey data. During 2008 and 2009, TxDOT and H-GAC conducted a household travel survey for the 8-county Houston-Galveston Region. The survey obtained general household and person data as well as travel activity data from over 5,800 households and over 18,600 persons for a single travel day (24 hours). A workplace travel survey was also conducted by TxDOT and H-GAC in 2010 and 2011 and involved the collection of travel data from employees and non-employees at 500 workplaces in the H-GAC region. Travel data was collected from nearly 1,800 employees of and nearly 3,000 visitors to the surveyed worksites.

Although no external travel survey has been performed since the 1995 Houston external travel survey, external volume and classification counts were collected by H-GAC in 2011. These counts are the basis for estimating external station control totals and auto and truck splits at the external stations.

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 5,113 detailed traffic analysis zones.

Trip generation is performed for fourteen trip purposes:

- Home-based Work Income Group 1 person trips (HBW-INC1);
- Home-based Work Income Group 2 person trips (HBW-INC2);
- Home-based Work Income Group 3 person trips (HBW-INC3);
- Home-based Work Income Group 4 person trips (HBW-INC4);
- Home-based Work Income Group 5 person trips (HBW-INC5);
- Home-based Nonwork Retail person trips to Retail (HBNW-RET);
- Home-based Nonwork ED1 (K-12) School Bus person trips (HBNW-ED1-SB);
- Home-based Nonwork person trips to ED1 by other (HBNW-ED1);
- Home-based Nonwork person trips Airport (HBNW-AIR);
- Home-based Nonwork person trips to Other (HBNW-OTHER);
- Non-home-based person trips – Work-based (NHB-WB);
- Non-home-based person trips – Non-work-based (NHB-NW);

- Taxi vehicle trips (TAXI);
- External-local auto vehicle trips (EXTL-AUTO);
- External-through auto vehicle trips (EXTHR-AUTO);
- External-through truck vehicle trips (EXTHR-TRK)

The HBNW-ED1 trip purpose excludes the person trip by school bus but includes those that use normal transit. The HBNW-ED1-SB purpose was defined as a separate trip purpose as 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 model. 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).

4.2.1. Trip Production

The H-GAC trip household production models use cross-classification trip production rates developed from the H-GAC 2008/09 Household Travel Survey data. These rates were developed for a three-way cross classification of households dimensioned by household size, number of workers, and by household income. In the model calibration process, some of the resulting rates were 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.

The trip production model determines the relationship between trips generated per household, number of workers, and household income in combination with household size. Thus, trip production rates were stratified by household size, household income and number of workers. The updated trip production rates are presented in Tables 4.1-4.8. The household survey revealed thats less than 1 percent of classified non-workers made work trips and hence the production rates do include work trip rates for zero-worker households.

Table 4.1 Home-Based Work Person Trips

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.013	0.024	0.023	0.026	0.031
	1	0.765	0.899	1.078	1.241	1.259
	2+	N/A	1.579	1.858	2.230	2.425
2	0	0.013	0.024	0.023	0.026	0.031
	1	0.854	1.034	1.124	1.259	1.303
	2+	N/A	1.858	2.184	2.416	2.602
3	0	0.013	0.024	0.023	0.026	0.031
	1	0.944	1.124	1.214	1.303	1.349
	2+	N/A	2.137	2.416	2.602	2.788
4	0	0.013	0.024	0.023	0.026	0.031
	1	0.989	1.169	1.259	1.349	1.393
	2+	N/A	2.276	2.555	2.741	2.927
5	0	0.013	0.024	0.023	0.026	0.031
	1	1.034	1.214	1.303	1.393	1.438
	2+	N/A	2.323	2.648	2.788	3.020

Source: H-GAC

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

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.058	0.074	0.641	1.262	2.759
	1	0.146	0.245	0.817	2.424	3.958
	2+	0.000	0.145	0.424	1.078	3.419
2	0	0.067	0.169	0.779	1.290	3.695
	1	0.125	0.182	0.975	3.264	5.431
	2+	0.000	0.145	0.878	1.819	3.929
3	0	0.076	0.234	0.596	2.119	4.204
	1	0.106	0.169	1.068	3.824	5.983
	2+	0.000	0.145	1.070	2.379	4.279
4	0	0.087	0.356	0.550	3.132	4.989
	1	0.098	0.128	1.374	4.290	6.443
	2+	0.000	0.145	1.093	2.975	4.481
5	0	0.105	0.422	0.505	4.976	6.467
	1	0.091	0.102	1.653	4.477	6.259
	2	0.000	0.145	1.124	3.727	4.718

Source: H-GAC

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

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.000	0.045	0.262	0.830	2.032
	1	0.000	0.010	0.311	1.176	1.516
	2+	0.000	0.011	0.057	0.098	0.138
2	0	0.000	0.016	0.209	0.622	1.551
	1	0.000	0.010	0.263	0.980	1.611
	2+	0.000	0.021	0.099	0.146	0.188
3	0	0.000	0.017	0.136	0.521	1.387
	1	0.000	0.010	0.204	0.852	1.706
	2+	0.000	0.032	0.142	0.195	0.239
4	0	0.000	0.003	0.104	0.570	1.260
	1	0.000	0.010	0.165	0.833	1.895
	2+	0.000	0.043	0.184	0.244	0.289
5	0	0.000	0.000	0.162	0.632	1.145
	1	0.000	0.010	0.126	0.833	2.085
	2+	0.000	0.054	0.227	0.293	0.339

Source: H-GAC

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

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.559	1.173	1.341	1.565	1.788
	1	0.652	1.411	1.628	1.955	2.172
	2+	0.000	1.143	1.416	1.611	1.742
2	0	1.005	1.732	1.900	2.124	2.347
	1	0.706	1.628	1.846	2.389	2.714
	2+	0.000	1.253	1.634	1.830	2.177
3	0	1.453	2.291	2.459	2.682	2.905
	1	0.760	1.792	2.008	2.714	3.149
	2+	0.000	1.416	1.851	2.048	2.505
4	0	1.900	2.738	2.905	3.129	3.465
	1	0.814	1.932	2.149	3.040	3.475
	2+	0.000	1.524	2.069	2.265	2.832
5	0	2.347	3.185	3.353	3.576	4.024
	1	0.869	2.172	2.389	3.258	3.692
	2+	0.000	1.634	2.287	2.483	3.158

Source: H-GAC

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

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.013	0.024	0.032	0.039	0.041
	1	0.010	0.021	0.027	0.039	0.047
	2+	0.000	0.007	0.018	0.039	0.047
2	0	0.011	0.019	0.027	0.046	0.055
	1	0.011	0.023	0.031	0.051	0.063
	2+	0.000	0.010	0.023	0.042	0.055
3	0	0.021	0.042	0.049	0.057	0.085
	1	0.012	0.025	0.036	0.062	0.079
	2+	0.000	0.015	0.028	0.046	0.061
4	0	0.024	0.049	0.057	0.067	0.103
	1	0.013	0.027	0.043	0.074	0.091
	2+	0.000	0.020	0.035	0.050	0.068
5	0	0.026	0.053	0.062	0.077	0.124
	1	0.015	0.032	0.049	0.084	0.101
	2+	0.000	0.024	0.040	0.055	0.076

Source: H-GAC

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

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.705	1.323	1.718	2.097	2.237
	1	0.539	1.144	1.467	2.116	2.562
	2+	0.000	0.376	0.962	2.125	2.560
2	0	0.882	1.839	2.191	2.568	3.591
	1	0.599	1.272	1.685	2.753	3.439
	2+	0.000	0.570	1.250	2.301	2.979
3	0	1.117	2.286	2.662	3.099	4.593
	1	0.658	1.373	1.964	3.391	4.316
	2+	0.000	0.789	1.504	2.478	3.340
4	0	1.293	2.653	3.077	3.631	5.594
	1	0.731	1.492	2.360	4.028	4.953
	2+	0.000	1.069	1.889	2.711	3.698
5	0	1.411	2.898	3.372	4.162	6.713
	1	0.814	1.713	2.639	4.546	5.471
	2+	0.000	1.300	2.178	3.005	4.118

Source: H-GAC

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

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.008	0.015	0.014	0.016	0.019
	1	0.307	0.384	0.430	0.538	0.615
	2+	0.000	0.737	0.899	1.106	1.253
2	0	0.008	0.015	0.014	0.016	0.019
	1	0.460	0.538	0.583	0.691	0.769
	2+	0.000	1.031	1.179	1.326	1.548
3	0	0.008	0.015	0.014	0.016	0.019
	1	0.615	0.691	0.737	0.844	0.922
	2+	0.000	1.326	1.473	1.548	1.798
4	0	0.008	0.015	0.014	0.016	0.019
	1	0.769	0.844	0.892	0.998	1.075
	2+	0.000	1.592	1.769	1.842	2.064
5	0	0.008	0.015	0.014	0.016	0.019
	1	0.922	0.998	1.045	1.153	1.229
	2+	0.000	1.842	2.035	2.131	2.284

Source: H-GAC

Table 4.8 Non-Home Based Other Person Trip Rates

Income Group	Number of Workers	1 Person Household	2 Person Household	3 Person Household	4 Person Household	5+ Person Household
1	0	0.764	1.546	2.161	2.593	3.169
	1	1.400	1.604	1.719	1.863	2.578
	2+	0.000	1.368	1.569	1.821	2.055
2	0	1.152	1.873	2.593	3.096	3.600
	1	1.400	2.030	2.078	2.291	3.008
	2+	0.000	1.597	2.008	2.259	2.471
3	0	1.584	2.305	3.025	3.600	4.105
	1	1.400	2.334	2.507	2.793	3.538
	2+	0.000	1.901	2.286	2.550	2.777
4	0	2.088	2.737	3.456	4.032	4.608
	1	1.400	2.582	2.793	3.295	4.010
	2+	0.000	2.185	2.521	2.842	3.028
5	0	2.593	3.241	3.961	4.464	5.041
	1	1.400	2.700	3.079	3.624	4.440
	2+	0.000	2.434	2.711	2.987	3.333

Source: H-GAC

4.2.2. Trip Attractions

Trip attraction rates have been updated for the 2012 Track-1 model based on the 2010/2011 TxDOT and H-GAC workplace 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. Tables 4.9 through 4.21 present the 2012 Track-1 trip attraction rates. Attraction rates were not developed for the HBNW-AIR trip purpose as the attractions are estimated based on the 2010/2011 airport special generator survey.. Truck trip demand is estimated outside the Track-1 model set via H-GAC CUBE Cargo-based truck model and not part of the Track-1 trip generation process,

Table 4.9 HBW Person Trip Attraction Rates – Income Group 1

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0120	0.0710	0.0680	0.1140	0.0480	0.0750	0.1710	0.2890	0.1859
2	0.0090	0.1290	0.0700	0.2070	0.1010	0.1080	0.1530	0.0340	0.0219
3	0.0110	0.1330	0.1080	0.1610	0.0590	0.0780	0.1010	0.0820	0.0527
4	0.0070	0.1170	0.0560	0.0770	0.0160	0.0730	0.0950	0.0830	0.0534
5	0.0110	0.1460	0.0470	0.0510	0.0300	0.0500	0.0950	0.3350	0.2155

Table 4.10 HBW Person Trip Attraction Rates – Income Group 2

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0200	0.0970	0.0970	0.2080	0.3460	0.2300	0.0890	0.4010	0.2579
2	0.0270	0.1440	0.0920	0.4460	0.2100	0.2590	0.4010	0.1470	0.0945
3	0.0160	0.1570	0.2000	0.2760	0.1350	0.1170	0.1990	0.1770	0.1138
4	0.0070	0.1800	0.1010	0.1670	0.0790	0.0800	0.0960	0.1190	0.0765
5	0.0220	0.1450	0.1740	0.0870	0.0860	0.0730	0.0750	0.3280	0.2110

Table 4.11 HBW Person Trip Attraction Rates – Income Group 3

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.1350	0.1540	0.2710	0.2330	0.5970	0.5090	0.3270	0.2103	0.8151
2	0.2190	0.2040	0.1640	0.2650	0.2320	0.2710	0.1860	0.1196	0.8121
3	0.2300	0.2860	0.2890	0.2420	0.1560	0.3480	0.3720	0.2393	0.8676
4	0.2700	0.2280	0.2960	0.2790	0.1710	0.2700	0.1320	0.0849	0.8676
5	0.2040	0.2350	0.1390	0.5380	0.1370	0.5790	0.3280	0.2110	1.0718

Table 4.12 HBW Person Trip Attraction Rates – Income Group 4

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.2620	0.2820	0.3340	0.2410	0.4230	0.1800	0.3270	0.2103	0.8151
2	0.1190	0.2570	0.2060	0.3150	0.2490	0.1910	0.3030	0.1949	0.8121
3	0.1610	0.3080	0.1770	0.3050	0.1780	0.3390	0.2580	0.1659	0.8676
4	0.2930	0.3000	0.2960	0.2000	0.1780	0.4340	0.4330	0.2785	0.8676
5	0.3200	0.2720	0.3850	0.2450	0.1620	0.3890	0.3280	0.2110	1.0718

Table 4.13 HBW Person Trip Attraction Rates – Income Group 5

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.2930	0.7400	0.3240	0.1900	0.1790	0.3640	0.3270	0.2103	0.8151
2	0.2040	0.4010	0.0720	0.1870	0.3180	0.4010	0.3470	0.2232	0.8121
3	0.1800	0.6020	0.0760	0.3380	0.2590	0.3380	0.1270	0.0817	0.8676
4	0.2990	0.4610	0.0570	0.4510	0.2050	0.3670	0.2490	0.1601	0.8676
5	0.2140	0.2740	0.0920	0.1750	0.3290	0.1760	0.3540	0.2277	1.0718

Table 4.14 Home Based Non-Work to Education-1 Person Trip Attraction Rates (Grade 12 and under)

Area Type	ED-1
1	7.529
2	3.903
3	7.735
4	7.978
5	5.989

Table 4.15 Home Based Non-Work to Education-1 on School Bus Person Trip Attraction Rates (Grade 12 and under)

Area Type	ED-1
1	32.701
2	46.391
3	26.264
4	41.872
5	23.400

Table 4.16 Home-Based Non-Work to Retail Person Trip Attraction Rates

Area Type	Retail
1	3.866
2	3.237
3	4.732
4	3.219
5	3.200

Table 4.17 Home Based Non-Work Other Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	Enroll A	Enroll B
1	0.4440	0.0000	1.4320	0.5060	2.5930	4.1080	0.5603	0.5557
2	0.4440	0.0000	1.7340	0.4770	1.0890	1.9290	0.5603	0.5557
3	0.4440	0.0000	1.2160	0.4420	1.0890	5.9660	0.5603	0.5557
4	0.4440	0.0000	1.8070	1.1910	3.7830	3.4580	0.5603	0.5557
5	0.4440	0.0000	1.8570	0.5960	6.3370	3.4980	0.5603	0.5557

Table 4.18 Non-Home-Based Work-Based Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0581	0.5570	0.6565	0.3618	0.2206	0.4249	0.2890	0.1951	0.1255
2	0.0923	0.3214	0.7951	0.4210	0.1740	0.2138	0.2236	0.1989	0.1279
3	0.0891	1.3949	0.4076	0.1810	0.1855	0.4961	0.2651	0.2349	0.1511
4	0.0886	0.3000	0.5441	0.3420	0.3939	0.3745	0.3857	0.2361	0.1519
5	0.0880	0.3979	0.3326	0.4274	0.2625	0.4010	0.4511	0.2585	0.1663

Table 4.19 Non-Home-Based Other Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.2309	2.7190	0.1095	0.1212	0.5024	0.5111	0.7640	0.4029	0.2592
2	0.1967	1.6456	0.2009	0.1160	0.2930	0.2202	0.5664	0.3991	0.2567
3	0.1999	3.9691	0.2274	0.2220	0.2815	0.6259	0.7879	0.3631	0.2335
4	0.2004	0.9650	0.3319	0.4640	0.6841	0.4665	1.2003	0.3619	0.2327
5	0.2010	1.0701	0.4334	0.4456	0.4375	0.4490	1.2129	0.3395	0.2183

Table 4.20 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 4.21 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	0.1180	0.0759
2	0.0154	0.0985	0.0731	0.0316	0.0621	0.0687	0.1266	0.1151	0.0740
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	0.0240	0.0784	0.0741	0.1507	0.1381	0.0888
5	0.0235	0.2090	0.0607	0.0199	0.0682	0.0616	0.1320	0.1227	0.0789

4.2.3. Special Generators

The 2012 Track-1 models treat the two commercial airports as special generators. The number of trip ends at the airports was estimated based on surveys done at the airports in 2010/11. This data collection involved intercept surveys of employees of and visitors to the airports at various activity locations (i.e., terminals, rental car sites, cargo sites). The trips captured through these surveys was expanded to a total person count that was derived from vehicle counts made at all vehicle entry/exit locations of the airports.

4.2.4 Non-resident travel

Due to the high concentration of hotels, motels, and seasonal housing on Galveston Island, the Bolivar Pennisula and the coastal portion of Brazoria County, generation of non-resident trips was also performed. An average Galveston Island hotel occupancy rate was applied against the number of hotel rooms on 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 was applied to estimated seasonal housing on Galveston Island, the Bolivar Pennisula and the coastal portion of Brazoria County to estimate occupied seasonal housing units. This estimate of seasonal housing units was then multiplied by a NHB trip rate yielded seasonal housing non-resident NHB trips. As part of the 2012 Track-1 model update, the estimate of seasonal housing units was updated using 2010 Census data and the estimate of hotel rooms updated using information from the Galveston Visitors Bureau.

4.2.4. Truck travel

Year 2012 truck travel was based on procedures developed by H-GAC using the Cube Cargo modeling software platform. Cube Cargo is a model of demand for the transport of goods and services. As with models used for individual travel, Cube Cargo contains the traditional steps of trip generation, trip distribution, and modal split. In models of individual travel, the results of the modal split will be in people or vehicles. In the freight modelling context used in Cube Cargo, the results of mode split is a matrix in tons. Additional modelling is required to determine how those tons are allocated to vehicles.

Whereas four-step travel demand models treat the generation and distribution of different trip types (e.g. Home-Based Work, Home-Based Other) separately, the Cube Cargo model similarly does so but in terms of commodities and by consumption and production. The model then distributes and matches up consumptions with productions and determines if the goods get there by truck or rail based on user supplied inputs.

In addition to the freight model component, Cube Cargo also produces estimates for other generators of regional truck traffic, in particularly light trucks, in terms of service vehicles – which are those that provide for deliveries, as well as other service, to household and employment centers. Therefore, the year 2012 truck demand was segmented by cargo and service trucks for both internal and external truck travel.

4.2.5. External Travel

External trip demand is separated into auto and truck demand and the total demand is controlled to match the counted station volumes at each external station.

External-local ruck demand comes from outside the four-step demand model process through H-GAC's Cube Cargo model, the external-local truck volume from these counts is set aside in lieu of the volumes from the Cargo model.

The counted auto volumes at each external station are separated into local and through auto volumes based on the local and through split from the most recent (1995) external travel survey. The local auto volumes are the basis for the external-local auto productions and each station. The through auto and truck volumes are used as inputs to a FRATAR process that grows the 1995 external-through auto trip table to a 2012 external-through auto trip table. Table 4.22

presents the external local and through auto and the external through truck volumes used in the 2012 model update.

Table 4.22 External Station Auto Volumes

EXTERNAL STATION	FACILITY & LOCATION	AUTO VOLUME		TRUCK VOLUME
		LOCAL	THROUGH	THROUGH
5114	SH 6 at Grimes Co. Line	10,380	820	270
5115	FM 362 at Grimes Co. Line	790	50	10
5116	FM 1774 at Grimes Co. Line	4,900	0	0
5117	US 290 at Washington Co. Line	12,270	680	180
5118	SH 159 at Austin Co. Line	2,820	150	50
5119	FM 529 at Austin Co. Line	1,220	0	0
5120	FM 1458 at Austin Co. Line	1,170	0	0
5121	IH 10 at Austin Co. Line	25,800	2,240	840
5122	SH 105 at Grimes Co. Line	4,470	550	120
5123	FM 1486 at Grimes Co. Line	620	100	30
5124	FM 149 at Grimes Co. Line	790	40	10
5125	FM 1791 at Walker Co. Line	780	0	0
5126	FM 1375 at Walker Co. Line	810	0	0
5127	IH 45 at Walker Co. Line	28,370	860	270
5128	SH 75 at Walker Co. Line	2,790	90	20
5129	Rogers Rd. at Walker Co. Line	390	0	0
5130	FM 1097 at Walker Co. Line	2,530	10	0
5131	Walker Rd. at San Jacinto Co. Line	1,430	0	0
5132	FM 3081 at San Jacinto Co. Line	1,110	10	0
5133	CR 321 (Boone Rd.) at Matagorda Co. Line	200	10	0
5134	FM 1725 at San Jacinto Co. Line	2,080	90	20
5135	FM 2025 at San Jacinto Co. Line	5,190	40	0
5136	US 59 at San Jacinto Co. Line	16,740	750	280
5137	FM 223 at San Jacinto Co. Line	670	50	10
5138	FM 2610 at Polk Co. Line	590	30	0
5139	SH 146 at Polk Co. Line	1,180	460	170
5140	FM 787 at Hardin Co. Line	750	230	100

5141	SH 105 at Hardin Co. Line	1,780	820	400
5142	FM 770 at Hardin Co. Line	1,730	90	20
5143	US 90 at Jefferson Co. Line	4,520	490	140
5144	IH 10 at Jefferson Co. Line	19,500	2,680	1,550
5145	SH 73/124 at Jefferson Co. Line	9,270	250	70
5146	Whites Ranch Rd. at Jefferson Co. Line	340	0	0
5147	FM 2611 at Matagorda Co. Line	1,550	0	0
5148	FM 521 at Matagorda Co. Line	2,240	110	10
5149	SH 35 at Matagorda Co. Line	5,230	180	40
5150	FM 1301 at Matagorda Co. Line	800	20	10
5151	FM 442 at Wharton Co. Line	2,270	20	0
5152	US 59 at Wharton Co. Line	13,880	1,540	660
5153	US 90A at Wharton Co. Line	4,540	50	10
5154	FM 2919 at Wharton Co. Line	750	0	0
5155	FM 1952 at Wharton Co. Line	630	0	0
5156	SH 36 at Austin Co. Line	3,530	50	10
5157	FM 1093 at Austin Co. Line	1,690	30	10
5158	FM 1406 at Jefferson Co. Line	1,230	0	0
5159	SH 87 at Jefferson Co. Line	facility closed		

4.2.6. Trip Generation Results

Table 4.23 summarizes the 2012 trip generation estimates by trip purpose.

Table 4.23 Regional Trip Estimates by Purpose

PURPOSE	2012 TRIPS		% OF TOTAL
HBW Income 1	180,396		
HBW Income 2	364,373		
HBW Income 3	607,917		
HBW Income 4	671,923		
HBW Income 5	1,035,604		
HBW Total		2,860,213	12.6%
HBNW-Educational 1 by School Bus	553,197		
HBNW-Educational 1 by Other	3,171,311		
HBNW Retail	4,037,495		
HBNW-Airport	79,142		
HBNW-Other	4,301,635		
HBNW - Total		11,589,583	51.0%
NHB-Work-Based	1,947,966		

NHB-Other	4,964,041		
NHB Total		6,912,007	30.4%
NON-RESIDENT	271,890		1.2%
EXTERNAL AUTO	226,715		1.0%
TAXI	57,927		0.3%
CARGO TRUCK (including external)	106,176		
SERVICE TRUCK	689,219		
Total Truck		795,395	3.5%
Regional Total		22,713,729	100.0%

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 of potential zonal destinations. The trip distribution of all HBW trips uses composite travel time as the measure of zonal impedance, while all other trip purposes make use of the more typical highway travel time. The composite time used in the HBW distribution is a combination of the AM peak period traffic assignment results and peak transit travel time. The zonal impedance is iteratively updated over the course of multiple applications of the trip distribution, mode choice and traffic assignment portions of the model set.

4.3.1. Zonal Impedance

Two measures of zonal impendance are used in the 2012 Track-1 model trip distribution process. For all trip purposes other than home-based work (HBW), zonal impedance is based on mid-day period highway travel time. For the five HBW trip purposes, the measure of zonal separation or impedance is a combination of AM peak period highway travel time and peak period transit travel time. This combined or "composite" travel time provides sensitivity in zonal attractiveness to changes in both highway and transit levels-of-service. The formulation of the composite time varies by income group to acknowledge the variation in sensitivity to transit service changes among households.

$$Composite\ Time = \frac{1}{\frac{1}{HT}+\frac{X}{TT}}$$

Where: HT = highway travel time (minutes)
TT = transit travel time (minutes)
X = weighting factor for each income group

An example application of the composite time formulation with example travel times is presented in Table 4.24. The weighting factors used in the feedback procedure represent the regional mode shares for each of the 5 HBW trip purposes.

Table 4.24 Composite Time Impedeance Example

Income Group	Weighting Factor	Highway Time	Transit Time	Composite Time	Decrease from Highway Time
1	0.056	25	30	23.9	4.5%
2	0.051	25	30	24.0	4.1%
3	0.024	25	30	24.5	2.0%
4	0.023	25	30	24.5	1.9%
5	0.033	25	30	24.3	0.8%

Both the AM peak period and mid-day period highway travel times used in the development of zonal impedances are derived from H-GAC's post-assignment speed estimation model. The post-assignment speed model uses volume-to-capacity (V/C) ratios from AM peak period and mid-day period assignments to estimate link-level travel times.

As part of model feedback process, the AM peak period and mid-day period impedances are iteratively updated based on new traffic assignment travel times.

4.3.2. Trip Table Development

The Disaggregate Trip Distribution Model, or Atomistic Model, a gravity-analogy-based model, is used for trip distribution modeling in the Houston-Galveston region. This model is used to produce 13 trip tables for the HBW-INC1, HBW-INC2, HBW-INC3, HBW-INC4, HBW-INC5, HBNW-ED1, HBNW-ED1-SB, HBNW-RETAIL, HBNW-OTHER, HBNW-AIR, NHB-WB, NHB-NW, Taxi, and External-local-Auto purposes. The distribution of HBNW-AIR is performed 'backwards' from the other purposes in that the trip ends at the airport are treated as productions and the trips ends at the home end are treated as attractions. 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 2012 traffic volumes at the external stations. The Atomistic model is a gravity-analogy trip distribution model which is enhanced in its treatment of intrazonal tirps. 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:

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

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 and the zonal impedances Track-1 trip distribution model also requires:

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

The 2012 Track-1 model update included calibration of new F-factors. Using F-factor calibration options of the ATOM software, F-factors were created using trip-length frequency distributions from the survey expanded trip tables using the same measure of impedance that is used in the distribution of trips. In other words, the AM peak period composite impedance-based trip length frequency of survey HBW trips and mid-day period highway impedance-based trip length frequency of survey trips for all other internal purposes were used in the development of 2012 Track-1 model F-factors. The F-factors were adjusted until the resulting trip length reasonably matched the survey observed trip length as shown in Table 4.25. The calibrated F-factors by purpose are presented in Appendix C.

Trip distribution bias 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 retained and updated in the 2012 Track-1 model set to improve trip flows, particularly on non-work flows.

Table 4.25 Survey Observed and Model Resulting Average Trip Length by Purpose

	2012 AVERAGE TRIP LENGTH (network minutes)	
PURPOSE	**SURVEY OBSERVED**	**MODELED**
HBW Income Group 1	19.0	18.4
HBW Income Group 2	20.8	19.9
HBW Income Group 3	20.8	19.8
HBW Income Group 4	22.4	21.2
HBW Income Group 5	22.9	21.9
HBNW-ED1	8.7	8.7

HBNW-Retail	11.0	10.9
HBNW-Airport	35.4	34.1
HBNW-Other	13.0	12.4
NHB Work-Based	12.9	11.9
NHB-Other	10.8	10.3
Taxi	12.9	12.2
External-Local Auto	40.4	37.1

Source: H-GAC Model Application Results

Bias factors were also updated for the 2012 Track-1 modelin part based on 2006-2010 ACS flow data. The combined HBW modeled trip table was compared to the ACS data at a district level. Revisions of HBW bias factors were made to encourage more intra-county HBW travel and to enhance work flows to various regional employment centers.

The 2012 Track-1 model also used bias-factors in the distribution of HBNW-ED1 trips to discourage trips from crossing the artificial (to the model) school district boundaries. Slight modifications of HBNW-Retail and HBNW-Other and NHB-Other bias factors were made to encourage travel among suburban communities in Fort Bend and Brazoria counties to activities just across the Harris County boundary.

4.4. Mode Choice

4.4.1. 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. 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.

4.4.2. Transit Fares

Year 2012 transit fares were used as transit fare inputs to 2012 model validation. Table 4.26 presents the year 2012 transit fares.

Table 4.26 Year 2012 Transit Fares

Local Bus	1.11
Light Rail	1.11
Express Bus	1.11
Commuter Bus	
0-10 miles	1.78
11-15 miles	2.89
16-20 miles	3.34
>20 miles	4.01

Source: Houston Metro

4.4.3. Parking Costs

Table 4.27 summarizes the estimated parking costs used at the four major activity centers, including the Houston CBD, Greenway Plaza, Texas Medical Center, and Uptown/Galleria. This variable is defined as an estimate of the actual (or average) out-of-pocket cost paid on a daily basis per vehicle.

Table 4.27 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	$0.47$2.42	$1.65
Uptown/Galleria	$0.07-$0.17	$0.10
UTMB Galveston	$1.10	$1.10

Source: Houston METRO

4.4.4. Model Choice Model

The Houston mode choice model is a nested logit model that addressed four separate auto and five different transit modes segmented among three different mode of access:

- Drive alone
- Two person
- Three person
- Four-plus person
- Transit-walk access Local Bus
- Transit-walk access Commuter Bus
- Transit-walk access Express Bus
- Transit-walk access Light Rail
- Transit-walk access Commuter Rail
- Transit-park-and-ride access Local Bus
- Transit-park-and-ride access Commuter Bus
- Transit-park-and-ride access Express Bus
- Transit-park-and-ride access Light Rail
- Transit-park-and-ride access Commuter Rail
- Transit-kiss-and-ride access Local Bus
- Transit-kiss-and-ride access Commuter Bus
- Transit-kiss-and-ride access Express Bus
- Transit-kiss-and-ride access Light Rail
- Transit-kiss-and-ride access Commuter Rail

The model was originally estimated based upon 1995 Home-Interview and On-Board Transit Rider Survey data and was re-calibrated locally observed travel values devired from the 2008/9

household suvery and 2010 transit origin-destination survey. Table 4.28 presents the target and model shares by mode.

Table 4.28 Year 2012 Mode Choice Modal Targets and Modeled Shares

Mode	Target Percentage	Modeled Percentage
HBW		
Drive Alone Auto	85.27%	85.53%
2 Person Auto	8.42%	8.09%
3+ Person Auto	2.18%	2.05%
Transit Walk Access	2.11%	2.39%
Transit Park-and-ride Access	1.61%	1.73%
Transit Kiss-and-ride Access	0.38%	0.21%
HBNW		
Drive Alone Auto	54.97%	54.77%
2 Person Auto	28.13%	28.09%
3+ Person Auto	16.43%	16.62%
Transit Walk Access	0.38%	0.44%
Transit Park-and-ride Access	0.05%	0.04%
Transit Kiss-and-ride Access	0.04%	0.04%
NHB		
Drive Alone Auto	58.25%	58.14%
2 Person Auto	26.43%	26.41%
3+ Person Auto	14.99%	15.11%
Transit Walk Access	0.24%	0.25%
Transit Park-and-ride Access	0.06%	0.06%
Transit Kiss-and-ride Access	0.03%	0.03%

A graphical depiction of the nested logit model structure for each trip purpose is displayed in Figure 4-1. The complete set of coefficient values for the Home-Based Work nested logit model is shown in Table 4.29. The Home-Based Non-Work and Non-Home Based values are presented in Tables 4.30 and 4.31, respectively.

Figure 4-1 H-GAC Regional Mode Choice Model – Nested Logit Model Structure

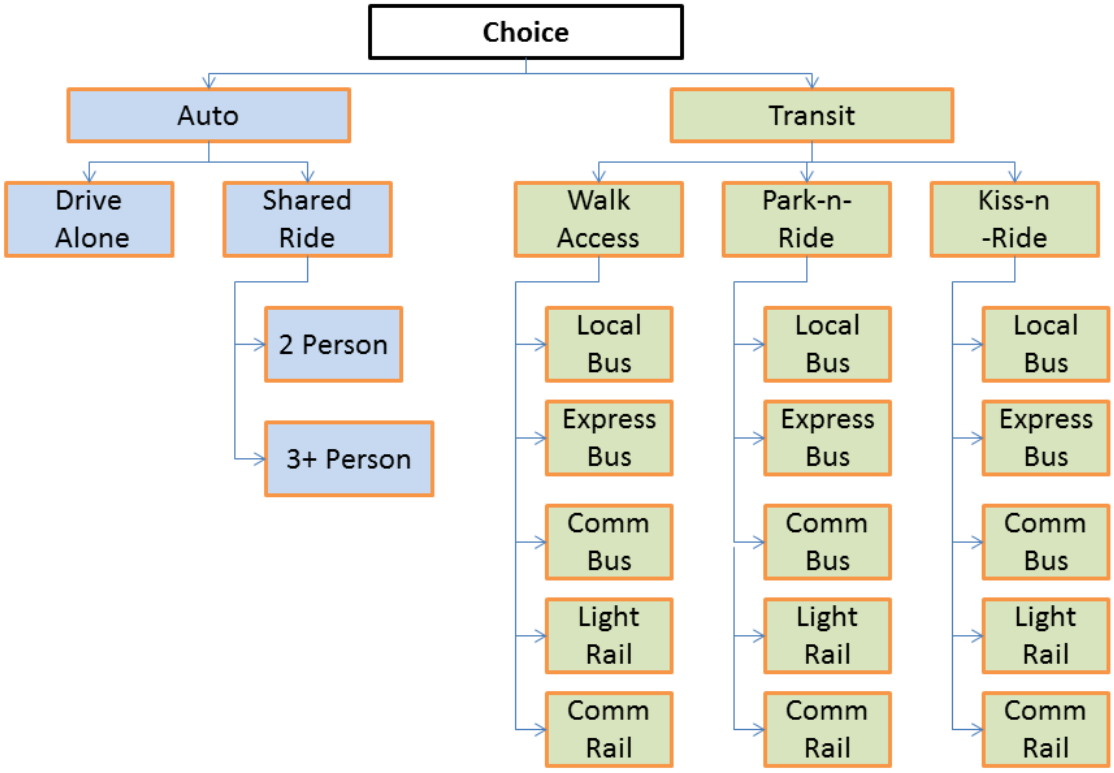


Table 4.29 Coefficient Values for Home-Based Work Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.022026	All modes
1 Wait less than 4.5 minutes	-0.022026	Transit
1 Wait over 4.5 minutes	-0.022026	Transit
Walk	-0.056796	Transit
Transfer time	-0.022026	Transit
Number of transfers	-0.088120	Transit
Transit fare (all)	-0.006144	Transit
Drive to transit time	-0.033045	Transit
Parking cost (all)	-0.015364	Highway
Auto Operating Cost (all)	-0.006145	Highway & Transit (Drive)
HOV/Toll Time Savings	+0.01542	Highway
Residential Density Indicator	+0.13947	Transit (Walk)
CBD	-0.44240	Transit
Texas Medical Center	+1.27232	Transit
Uptown	-0.62705	Transit
Greenway	-0.59310	Transit
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 2/3+	0.60000	Highway

Table 4.30 Coefficient Values for Home-Based Non-Work Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.01727	All modes
1st Wait time	-0.01727	Transit
Walk	-0.03454	Transit
Transfer time	-0.01727	Transit
Transit fare (all)	-0.00592	Transit
Parking cost (all)	-0.01479	Highway
Auto Operating Cost (all)	-0.00592	Highway & Transit (Drive)
HOV/Toll Time savings	+0.01270	Highway
Household Siz 2 Person 3 Person	 +0.07427 +0.44870	 Highway
Residential Density Indicator	+0.07767	Transit (Walk)
CBD	-3.1971	Transit
Texas Medical Center	-0.3714	Transit
Uptown	-1.5919	Transit
Greenway	-2.6730	Transit
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 2/3+	0.60000	Highway

Table 4.31 Coefficient Values for Non-Home Based Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.02370	All modes
1st Wait time	-0.02370	Transit
Walk	-0.04740	Transit
Transfer time	-0.02370	Transit
Transit fare (all)	-0.00562	Transit
Parking cost (all)	-0.01404	Highway
Auto Operating Cost (all)	-0.00562	Highway & Transit (Drive)
HOV/Toll time savings	+0.01660	Highway
CBD	-2.29877	Transit
Texas Medical Center	-0.03953	Transit
Uptown	-0.52611	Transit
Greenway	-0.56524	Transit
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 2/3+	0.60000	Highway

4.4.5. 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 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 4.32 - 4.34 summarize the final set of bias constant values for each trip purpose.

Table 4.32 Mode Bias Constants – Home Based Work Mode Choice Model

Constant	Income Level				
	1	2	3	4	5
Drive Alone	0	0	0	0	0
2 Person	-1.86317	-1.96686	-2.14118	-2.4557	-2.63028
3+ Person	-2.71114	-2.85619	-3.03592	-3.43329	-3.69858
Walk to Local Bus	0.685282	-0.66532	-1.91298	-3.35482	-4.65052
Walk to Express Bus	1.014948	-0.1643	-1.91707	-3.23048	-4.7453
Walk to Commuter Bus	-0.28086	-1.18585	-2.01078	-3.41898	-3.99212
Walk to Light Rail	7.062734	1.162207	1.019214	0.064667	-1.55092
Walk to Commuter Rail	-0.28086	-1.18585	-2.01078	-3.41898	-3.99212
PNR to Local Bus	-2.24991	-2.74073	-2.67097	-3.18275	-3.75303
PNR to Express Bus	-1.50781	-2.28376	-2.53382	-3.15845	-4.11039
PNR to Commuter Bus	-3.5046	-3.12858	-2.66612	-2.5565	-2.53478
PNR to Light Rail	1.773	2.60707	3.759599	2.265038	-0.30165
PNR to Commuter Rail	-3.5046	-3.12858	-2.66612	-2.5565	-2.53478
KNR to Local Bus	-1.80047	-3.09036	-4.25384	-4.48418	-5.46334
KNR to Express Bus	-2.03099	-3.7145	-4.06948	-4.89022	-5.33044
KNR to Commuter Bus	-25.6698	-5.66123	-4.65197	-4.98357	-5.30232
KNR to Light Rail	1.28701	1.524902	2.206163	0.315285	-2.19132
KNR to Commuter Rail	1.28701	1.524902	2.206163	0.315285	-2.19132
Walk to Premium Transit	-25.6698	-5.66123	-4.65197	-4.98357	-5.30232

Table 4.33 Mode Bias Constants – Home Based Non-Work Mode Choice Model

Constant	Income Level				
	1	2	3	4	5
Drive Alone	0	0	0	0	0
2 Person	-0.39649	-0.49237	-0.50732	-0.5577	-0.60522
3+ Person	-1.59881	-1.74739	-1.78997	-1.88558	-1.97768
Walk to Local Bus	-0.59491	-1.87484	-2.75604	-3.33669	-4.20075
Walk to Express Bus	-0.28475	-1.73088	-2.21339	-3.14275	-3.92794
Walk to Commuter Bus	1.345192	0.884526	0.669508	-0.36733	-0.27215
Walk to Light Rail	-0.11773	-1.58254	-2.21622	-2.59828	-2.65925
Walk to Commuter Rail	-0.11773	-1.58254	-2.21622	-2.59828	-2.65925
PNR to Local Bus	-3.4799	-4.76716	-4.62763	-5.51621	-6.00996
PNR to Express Bus	-30.1347	-4.29287	-3.86838	-4.5788	-5.4355
PNR to Commuter Bus	-3.45257	-3.38864	-3.59012	-3.21754	-2.96006
PNR to Light Rail	-2.34043	-2.97585	-3.04866	-2.92349	-4.06727
PNR to Commuter Rail	-2.34043	-2.97585	-3.04866	-2.92349	-4.06727
KNR to Local Bus	-3.1858	-3.78267	-5.4	-5.62365	-6.17042
KNR to Express Bus	-2.43817	-3.68337	-5.49404	-3.01003	-6.08126
KNR to Commuter Bus	-4.32435	-4.60712	-5.07184	-4.86535	-4.21941
KNR to Light Rail	-3.01699	-5.03868	-4.48665	-4.4957	-5.76227
KNR to Commuter Rail	-3.01699	-5.03868	-4.48665	-4.4957	-5.76227
Walk to Premium Transit	-1.40713	-2.51812	-3.63039	-4.12648	-4.92085

Table 4.34 Mode Bias Constants – Non-Home Based Mode Choice Model

Constant	Value
Drive Alone	0
2 Person	0.42269
3+ Person	0.66615
Walk to Local Bus	-2.6347
Walk to Express Bus	-1.86306
Walk to Commuter Bus	-0.21029
Walk to Light Rail	-1.68114
Walk to Commuter Rail	-0.21029
PNR to Local Bus	-4.07481
PNR to Express Bus	-3.53143
PNR to Commuter Bus	-1.6471
PNR to Light Rail	-1.79596
PNR to Commuter Rail	-1.6471
KNR to Local Bus	-3.9913
KNR to Express Bus	-4.71818
KNR to Commuter Bus	-3.10261
KNR to Light Rail	-3.9913
Walk to Premium Transit	-3.22308

The product of the mode choice models of the 2012 Track-1 model are daily auto vehicle and transit trips segmented by trip purpose, mode and income. The auto trip tables are portrayed in Table 4.35.

Table 4.35 Mode Choice Auto Trip Tables

PURPOSE	MODE	INCOME GROUP				
		1	2	3	4	5
HBW	Drive-Alone	✓	✓	✓	✓	✓
	2-person	✓	✓	✓	✓	✓
	3+-person	✓	✓	✓	✓	✓
HBNW	Drive-Alone	✓	✓	✓	✓	✓
	2-person	✓	✓	✓	✓	✓
	3+-person	✓	✓	✓	✓	✓
NHB	Drive-Alone	✓	✓	✓	✓	✓
	2-person	✓	✓	✓	✓	✓
	3+-person	✓	✓	✓	✓	✓

4.5. Time-of-Day Models

Following mode choice modeling, the 2012 Track-1 models converted the daily post-mode choice trip tables, the external auto trip tables and the truck tables from the Cargo model to time-of-day trip tables. The process for developing the time-of-day trip tables is the same as in the 2009 Track-1 models; the use of diurnal trip table factors. The diurnal trip table factors converted the daily auto vehicle trip tables from mode choice to time-of-day trip tables and impart of the appropriate directionality to the time-of-day demand. The diurnal trip tables factors that converted the post-mode choice vehicle trips by trip purpose were updated with data from

the 2008/09 household survey. The diurnal trip table factors used to factor the daily truck trip tables from Cargo were developed from TxDOT time-of-day vehicle classification counts while the diurnal trip table factors used to convert the daily external auto trips to time-of-day trip tables were created using the H-GAC 2011 external traffic counts.

Using the diurnal trip table factors, the daily demand was factored to represent demand for the following five time periods:

- AM peak period (3 hours)
- Mid-day period (6 hours)
- PM peak period (4 hours)
- Evening period (3 hours)
- Overnight period (8 hours)

During the iterative feedback applications of the 2012 Track-1 models, only AM peak period and mid-day period trip table factoring were performed. These two time periods were the basis for the iterative cycle of trip-distribution, mode choice, traffic assignment and convergence assessment. Upon achievement of convergence, the time-of-day trip tables were developed for the other three times-of-day.

4.6. Trip Assignment

4.6.1. Traffic Trip Assignment Methodology

The AM peak and mid-day period auto trip tables from mode choice were prepared for assignment to the AM peak period and mid-day period highway networks, respectively as part of the iterative application of the assignment model during congestion feedback. Following achievement of convergence , the PM peak, evening and overnight period trip tables were assigned to the corresponding time-of-day network.

The 2012 Track-1 model uses a multimodal multiclass generalized cost (G/C) assignment methodology to facilitate development of toll demand. As mentioned in section 3.2.3 of this report, toll costs are coded onto the links which contain the toll plazas/booths. The toll costs were converted to time using a values-of-time. The values of time vary by trip purpose, mode, and income group. To accommodate a 3-tiered value-of-time scheme (low, medium and high income) among certain trip purpose/mode combinations, the 5 income group segmentation present in the models through mode-choice is collapsed to three groups for all trip purpose/mode combinations except for work-related drive alone demand. A single value-of-time is used for external auto demand while the truck demand was maintained in the cargo and service truck categories with their own values-of-time. Table 4.36 presents the values of time used in the G/C assignment.

Table 4.36 Assignment Values-of-Time

PURPOSE	INCOME	MODE	VOT ($/hr.)
Work Related	1	Drive Alone	$9.60
Work Related	2	Drive Alone	$15.04
Work Related	3	Drive Alone	$20.48
Work Related	4	Drive Alone	$27.52
Work Related	5	Drive Alone	$37.12
Non-Work	Low (1-2)	Drive Alone	$7.03
Non-Work	Medium(3)	Drive Alone	$13.44
Non-Work	High (4-5)	Drive Alone	$23.65
Work Related	Low (1-2)	2 Person	$21.56
Work Related	Medium(3)	2 Person	$35.84
Work Related	High (4-5)	2 Person	$56.56
Non-Work	Low (1-2)	2 Person	$12.30
Non-Work	Medium(3)	2 Person	$23.52
Non-Work	High (4-5)	2 Person	$41.39
Work Related	Low (1-2)	3+ Person	$30.80
Work Related	Medium(3)	3+ Person	$51.20
Work Related	High (4-5)	3+ Person	$80.80
Non-Work	Low (1-2)	3+ Person	$17.57
Non-Work	Medium(3)	3+ Person	$33.60
Non-Work	High (4-5)	3+ Person	$59.12
Service Vehicle	n/a	n/a	$40.00
Cargo Truck	n/a	n/a	$64.00
Other (External, Taxi)	n/a	n/a	$18.94

In addition to the aggregation of five income groups to three among worked-related shared ride and all non-work-related demand, NHB-WB demand was combined with HBW demand by mode and by income group. The traffic assignment, therefore, involved the simultaneous assignment of 23 different classes of demand as listed below.

- Classes 1-5: Work-related drive-alone income groups 1-5;
- Classes 6-8: Non-work drive alone income groups low (1-2), medium (3), high (4-5);
- Classes 9-11: Work-related shared ride 2 person income groups low (1-2), medium (3), high (4-5);
- Classes 12-14: Non-work SR shared ride 2 person income groups low (1-2), medium (3), high (4-5);
- Classes 15-17: Work related shared ride 3+ person income groups low (1-2), medium (3), high (4-5);
- Classes 18-20: Non-work shared ride 3+ person income groups low (1-2), medium (3), high (4-5);
- Class 21: Service truck;
- Class 22: Cargo truck;

- Class 23: External.

The generalized cost function used in the time-of-day traffic assignment was as follows:

$$G_{n+1} = T_{n+1} + F_l/VOT_{p,o}$$

Where G_{n+1} = generalized time cost for iteratin n+1
T_{n+1}= link travel time for iteration n + 1
F_l = link toll cost
$VOT_{p.o}$= value of time for each trip purpose (work-related, non-work related) and occupancy and income group

Link travel time is based on the BRP volume-delay function (VDF) which was represented by

$$T_{n+1} = \left(1 + \alpha\left(v/c\right)^{\beta}\right) \times T_0$$

Where: T_0 = free-flow link travel time
T_{n+1}= link travel time for iteration n + 1
v = user equilibrium link volume from iterations 1 to n
c = link capacity
α, β= coefficients

The 2012 Track-1 model assignment validation included adjustment of the VDF parameters to improve performance of the assignment model. The 2012 Track-1 assignment model uses two sets of VDF parameters, as shown in Table 4.37, to reflect the response to congestion in the assignment.

Table 4.37 Assignment VDF Parameters

Facility Type	α	β
Freeway/Tollways/Managed Lanes	0.3	5.5
Other	0.4	5.5

The 2012 Track-1 assignment used the bi-conjugate Frank Wolfe (BCFW) user equilibrium algorithm due to its faster computation time and ability to achieve tighter convergence. The algorithm is coded into a CUBE traffic assignment script which also makes use of five convergence criteria plus a sixth criteria involving a count on the number of iterations. The assignment ends either when all five criteria are satisfied or when the maximum number of iterations is reached. Table 4.38 lists the six assignment criteria and stopping criteria associated with each.

Table 4.38 Assignment Stopping Criteria

CRITERIA	STOPPING VALUE
Gap	0.0001
Relative Gap	0.0001
Average Absolute Difference (AAD)	0.01
Relative Average Absolute Difference (RAAD)	0.0001
RMSE	0.1
Iterations	40

4.7. Post-Assignment Speed Estimation

Time-of-day highway speeds are developed from a post-assignment operational speed model that contains procedures adapted from the *Highway Capacity Manual* (HCM) methodology. The procedures used in this model employ different methodologies to estimate freeway and non-freeway link speeds are estimated. Freeway speed is estimated as 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 (based on link distances), 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.

The V/C ratios that served as input to the speed model are output from the time-of-day assignment. Since capacities used during the equilibrium assignment represent LOS E, the resulting link's V/C ratio were applied to the speed model to develop a time-of-day speed. In other words, the traffic assignment results are post-processed to compute a estimated congested speed for the time period of the assignment based on the assigned V/C ratio.

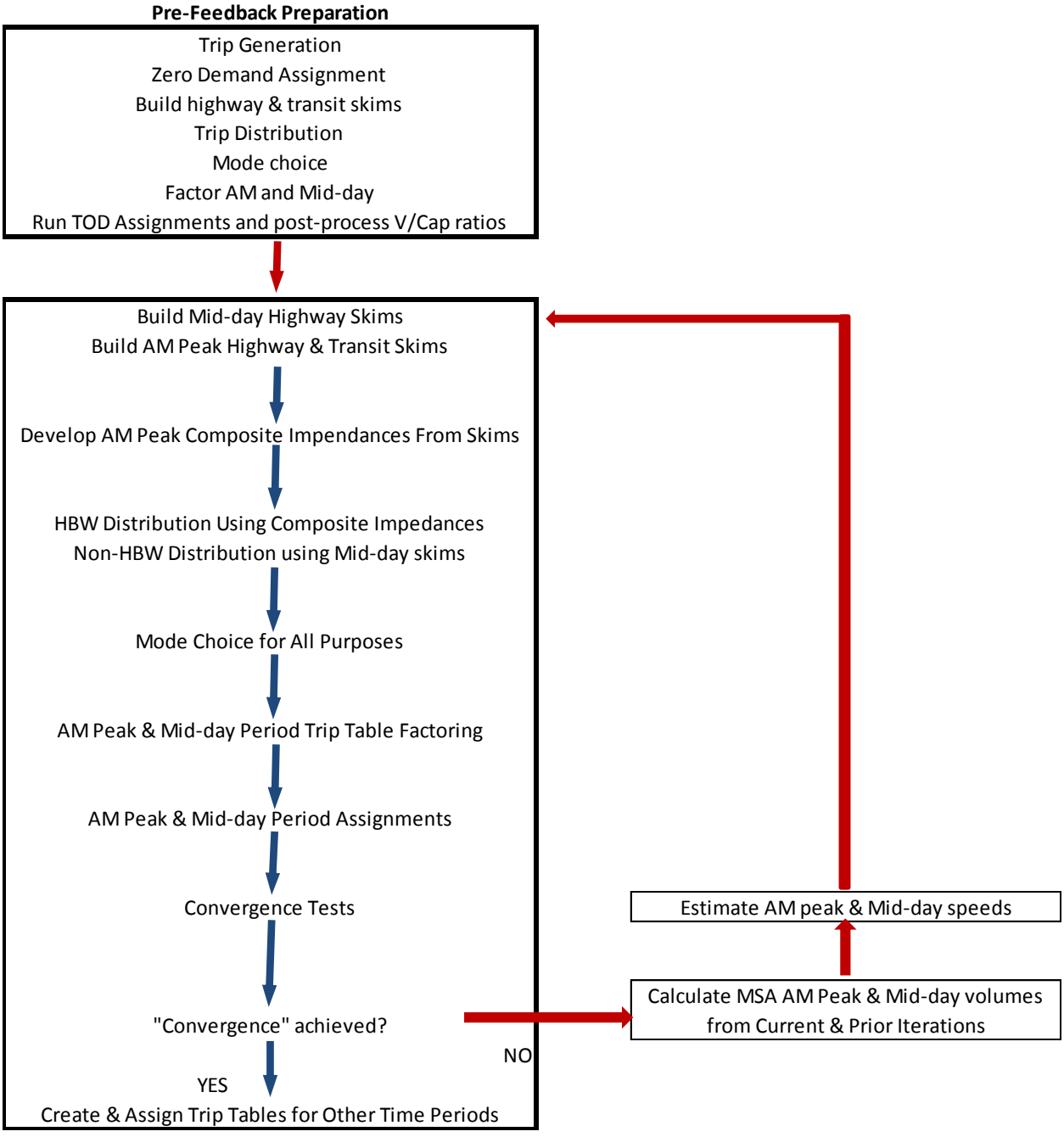
4.8. Iterative Congestion Feedback

As previously mentioned, the 2012 Track-1 models used two measures of zonal impedance in the distribution of trip ends. These impedance measures were iteratively updated following traffic assignment and fed-back to the trip distribution models for repititave applications of the trip distribution-mode choice and traffic assignment steps.

For HBW trips, a composite measure of AM peak period congestion was fed-back. The composite measure is developed by combining highway travel times based upon post-processed speeds from an AM peak period traffic assignment and transit travel time based on peak transit service levels. The technique used to feedback congested travel times to the non-work trip distribution process used post-procesed speeds from a mid-day period traffic

assignment Figure 4-2 presents a diagram of the model application process with inclusion of the feedback component.

Figure 4-2 Feedback Process



Both the HBW and non-work feedback used the Method of Successive Average (MSA) technique to calculate values of the traffic volumes to be used to calculate the travel times to be fed-back to trip distribution. In the case of HBW feedback, MSA-based AM peak period link volumes were calculated and input to the post-assignment speed estimation model to estimate AM peak period times for the composite time feedback. For non-work trip purpose feedback,

MSA mid-day period assignment link volumes were calculated and input to the post-assignment speed estimation model to estimate mid-day period travel times.

4.8.1. Measurement of Convergence

The 2012 Track-1 model iterative feedback process relied on several forms of measurement of equilibrium or stability and more than one procedure for quantifying change between iterations. These measures dealt with changes among iterations of the model set at the link, trip table and travel time matrix levels.

The trip table-based measures of stability were based on the HBW drive alone and the combined HBNW post-mode choice modal trip tables.

Zonal impedance matrices were also part of the convergence process. As two different measures of zonal impedance were used in feedback to trip distribution, the convergence process measures stability of two different zonal impedances. As the HBW trip purpose was segmented by income to facilitate the use of composite impedance, one of five possible measures of AM peak composite impedance were used for convergence measurement. The other impedance-based convergence measure was the mid-day zonal impedance.

The statistical measures of stability among these two matrix based measures used in the 2012 Track-1 models were root mean square change (RMSC) and a statistic named total misplaced flow (TMF). TMF measures the sum of the absolute values of cell differences divided by the sum of all cell values.

The 2012 Track-1 models also included two measures of link-level stability for convergence evaluation. The link-level measures of stability were the percent of links for which the change in link assigned mid-day period volume between iterations is greater than five percent and the GEH statistic. The GEH statistic is a formulation used to compare two sets of traffic volumes, but is not a pure statistical test. The formulation of the statistic is:

$$GEH = \sqrt{\frac{2(M-C)^2}{M+C}}$$

Where M is current iteration volume
and C is the previous iteration volume

A second link-based volume change measure was the percent of links for which the change in link assigned mid-day period volume between iterations is greater than five percent.

In order for convergence or “stability” to be achieved both criteria from among each criteria group (link change, trip table change, skim table change) must be met. In addition to the convergence measures, the feedback process stopping criteria also included a count on the number of iterations. This criteria is included as a practical need to keep model run times from becoming a hindrance to efficient use of the models. The maximum number of iterations was been set to 6 iterations. Convergence is declared if the statistics of any three of the measures (i.e., change in link volumes, % TMF of trip tables or % RMSC of skims) achieve the target value.

For the 2012 Track-1 model validation, the link change criteria were consistently satisfied before other criteria, usually after three iterations of feedback. Table 4.39 presents the convergence measurement criteria, the statistic values that represent convergence and convergence statistic values achieved in the 2012 Track-1 model validation. The 2012 Track-1 model achieved these convergence results after three iterations.

Table 4.39 Convergence Measure and Associated "Convergence" Values

Measure	Value of Convergence	Model Results
% Links Over 5% Change in AM Peak volume	5.0%	1.4%
%Links Over 5% GEH – AM Peak volume	3.0%	0.4%
% Links Over 5% Change in mid-day volume	5.0%	2.7%
% Links Over 5% GEH – mid-day volume	3.0%	0.2%
% TMF – HBW Drive-Alone Trip Table	2.0%	4.2%
% TMF – HBNW Drive-Alone Trip Table	1.0%	0.0%
%RMSC – HBW Income Group 1 Composite Skim	0.10%	0.15%
% RMSC mid-day 3+ Person Pay Skim	0.10%	0.00%

4.9. Assignment Validation

Following the establishment of stability or convergence using the iterative feedback procedures among the AM peak period and mid-day period assignments, traffic assignments were performed for the three other time periods. The link volume results of assignments for the 5 times periods were then combined for comparison to the daily traffic counts.

Table 4.40 summarizes the assigned and counted travel both on the basis of volume and vehicle miles of travel (VMT) by aggregated road type. These results reflect links with counts only. The detailed road types used in designation of links for purposes of link capacity have been collapsed to five categories of road type.

Table 4.41 summarizes the assigned and counted travel by area type on the basis of both volume and VMT.

Table 4.42 summarizes the counted and assigned volumes and VMT among the eight counties that make up the H-GAC modeling region.

Table 4.40 Year 2012 VMT by Roadway Type

Roadway Type	Number of Links With Counts	Counted Volume on Links With Counts	Assigned Volume on Links With Counts	Assigned Volume as Percent of Counted Volume	Counted VMT on Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
Freeway	435	27,656,648	27,898,747	100.9%	5,553,712	5,6075,417	101.0%
Toll Roads	52	1,658,050	1,686,728	101.7%	3,369,040	3,459,499	102.7%
Prin. Arterial	765	8,380,779	8,198,827	97.8%	16,812,669	16,440,928	97.8%
Other Arterial	1,249	7,038,553	6,476,896	92.0%	14,179,461	13,042,812	92.0%
Collectors	436	1,131,117	1,040,000	91.9%	2,288,016	2,111,691	92.3%
Region	2,937	45,865,146	45,301,198	98.8%	92,187,898	91,130,347	98.9%

Table 4.41 Year 2012 VMT by Area Type

Area Type	Number of Links With Counts	Counted Volume on Links With Counts	Assigned Volume on Links With Counts	Assigned Volume as Percent of Counted Volume	Counted VMT on Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
CBD	0						
Urban	142	9,650,229	10,477,846	108.6%	19,300,458	20,955,692	108.6%
Suburban	664	19,728,694	18,865,781	95.6%	39,522,664	37,826,508	95.7%
Fringe Suburban	908	11,645,925	10,865,776	93.3%	23,316,748	21,753,095	93.3%
Rural	1,225	4,869,246	5,091,794	104.6%	10,048,027	10,595,051	105.4%
Region	2,937	45,865,146	45,301,198	98.8%	92,187,898	91,130,347	98.9%

Table 4.42 Year 2012 VMT by County

County	Number of Links With Counts	Counted Volume on Links With Counts	Assigned Volume on Links With Counts	Assigned Volume as Percent of Counted Volume	Counted VMT on Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
Harris	775	30,268,067	30,530,623	100.9%	60,600,374	61,159,194	100.9%
Brazoria	421	2,569,313	2,514,175	97.9%	5,197,446	5,104,910	98.2%
Ft. Bend	369	3,848,265	3,475,651	90.3%	7,746,038	6,986,073	90.2%
Waller	196	825,701	725,328	87.8%	1,652,240	1,452,896	87.9%
Montgomery	375	3,631,874	3,580,330	98.6%	7,291,625	7,194,800	98.7%
Liberty	256	901,903	923,715	102.4%	1,838,503	1,883,357	102.4%
Chambers	208	915,219	944,926	103.2%	2,012,649	2,112,356	105.0%
Galveston	337	2,904,804	2,606,450	89.7%	5,849,023	5,236,760	89.5%
Region	2,937	45,865,146	45,301,198	98.8%	92,187,898	91,130,347	98.9%

5. HPMS VMT ADJUSTMENT

5.1. INTRODUCTION

The 2012 Track-1 model validation necessitated re-calculation of 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 Track-1 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 (2012) model estimated regional VMT against regional 2012 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 2012 estimated regional VMT to HPMS estimated 2012 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.

Table 5.1 2012 HPMS VMT

County	HPMS VMT
Brazoria	5,868,875
Chanmbers	2,494,079
Fort Bend	9,156,407
Galveston	5,545,105
Harris	96,143,407
Liberty	2,119,652
Montgomerty	11,365,407
Waller	1,914,405
Total Non-Toll VMT	***134,605,666***
Brazoria	12
Chanmbers	31,904
Fort Bend	66,004
Galveston	675
Harris	7,953,848
TotalToll VMT	***8,052,443***
Total 2012 Regional HPMS VMT	**142,658,109**

HPMS estimated average non-summer weekday travel (ANSWT)
= (HPMS AADT) * (AADT to Non-Summer Weekday Travel Adjustment Factor[A])
= (142,658,109) * (1.0722)
= 152,958,024
A – Provided by Dennid Perkinson, TTI, August 2014

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)
= (152,958,024) / (168,168,738)
= 0.90955

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.

APPENDIX A
NON-CENTROID SPEEDS & HOURLY CAPACITIES

Table A.1 Hourly Capacity and Initial Speed for Assignment

Area Type	Facility Type	Lanes	Speed	Hourly Capacity
1	1	2	50	4222
1	1	3	50	6333
1	1	4	50	8444
1	1	5	50	10556
1	1	6	50	12667
1	1	7	50	14778
1	1	8	50	16889
2	1	2	51	4444
2	1	3	51	6667
2	1	4	51	8889
2	1	5	51	11111
2	1	6	51	13333
2	1	7	51	15556
2	1	8	51	17778
3	1	2	57	4444
3	1	3	57	6667
3	1	4	57	8889
3	1	5	57	11111
3	1	6	57	13333
3	1	7	57	15556
3	1	8	57	17778
4	1	2	59	4385
4	1	3	59	6578
4	1	4	59	8770
4	1	5	59	10963
4	1	6	59	13155
5	1	2	62	4299
5	1	3	62	6449
5	1	4	62	8598
5	1	5	62	10748
1	2	2	52	5022
1	2	3	52	7133
1	2	4	52	9244
1	2	5	52	11356
1	2	6	52	13467
1	2	7	52	15578
1	2	8	52	17689
2	2	2	52	5244

2	2	3	52	7467
2	2	4	52	9689
2	2	5	52	11911
2	2	6	52	14133
2	2	7	52	16356
2	2	8	52	18578
3	2	2	55	5244
3	2	3	55	7467
3	2	4	55	9689
3	2	5	55	11911
3	2	6	55	14133
3	2	7	55	16356
3	2	8	55	18578
4	2	2	59	5099
4	2	3	59	7249
4	2	4	59	9398
4	2	5	59	11548
5	2	2	64	5099
5	2	3	64	7249
5	2	4	64	9398
5	2	5	64	11548
1	3	2	51	4000
1	3	3	51	6000
1	3	4	51	8000
1	3	5	51	10000
1	3	6	51	12000
1	3	7	51	14000
1	3	8	51	16000
2	3	2	52	4444
2	3	3	52	6667
2	3	4	52	8889
2	3	5	52	11111
2	3	6	52	13333
2	3	7	52	15556
2	3	8	52	17778
3	3	2	62	4444
3	3	3	62	6667
3	3	4	62	8889
3	3	5	62	11111
3	3	6	62	13333
3	3	7	62	15556

3	3	8	62	17778
4	3	2	62	4385
4	3	3	62	6578
4	3	4	62	8770
4	3	5	62	10963
5	3	2	64	4299
5	3	3	64	6449
5	3	4	64	8598
5	3	5	64	10748
1	4	2	52	4800
1	4	3	52	6800
1	4	4	52	8800
1	4	5	52	10800
1	4	6	52	12800
1	4	7	52	14800
1	4	8	52	16800
2	4	2	52	5244
2	4	3	52	7467
2	4	4	52	9689
2	4	5	52	11911
2	4	6	52	14133
2	4	7	52	16356
2	4	8	52	18578
3	4	2	55	5244
3	4	3	55	7467
3	4	4	55	9689
3	4	5	55	11911
3	4	6	55	14133
3	4	7	55	16356
3	4	8	55	18578
4	4	2	59	5185
4	4	3	59	7378
4	4	4	59	9570
4	4	5	59	11763
5	4	2	64	5099
5	4	3	64	7249
5	4	4	64	9398
5	4	5	64	11548
1	5	2	57	4325
1	5	3	57	6487
1	5	4	57	8649

1	5	5	57	10811
1	5	6	57	12974
1	5	7	57	15136
1	5	8	57	17298
2	5	2	58	4552
2	5	3	58	6828
2	5	4	58	9104
2	5	5	58	11381
2	5	6	58	13657
2	5	7	58	15933
2	5	8	58	18209
3	5	2	60	4547
3	5	3	60	6821
3	5	4	60	9095
3	5	5	60	11369
3	5	6	60	13642
3	5	7	60	15916
3	5	8	60	18190
4	5	2	67	4544
4	5	3	67	6816
4	5	4	67	9089
4	5	5	67	11361
5	5	2	71	4538
5	5	3	71	6807
5	5	4	71	9076
5	5	5	71	11345
1	6	2	60	5050
1	6	3	60	7212
1	6	4	60	9374
1	6	5	60	11536
1	6	6	60	13699
1	6	7	60	15861
1	6	8	60	18023
2	6	2	60	5402
2	6	3	60	7678
2	6	4	60	9954
2	6	5	60	12231
2	6	6	60	14507
2	6	7	60	16783
2	6	8	60	19059
3	6	2	63	5347

3	6	3	63	7621
3	6	4	63	9895
3	6	5	63	12169
3	6	6	63	14442
3	6	7	63	16716
3	6	8	63	18990
4	6	2	66	5294
4	6	3	66	7566
4	6	4	66	9839
4	6	5	66	12111
5	6	2	71	5088
5	6	3	71	7357
5	6	4	71	9626
5	6	5	71	11895
1	7	2	57	4325
1	7	3	57	6487
1	7	4	57	8649
1	7	5	57	10811
1	7	6	57	12974
1	7	7	57	15136
1	7	8	57	17298
2	7	2	57	4552
2	7	3	57	6828
2	7	4	57	9104
2	7	5	57	11381
2	7	6	57	13657
2	7	7	57	15933
2	7	8	57	18209
3	7	2	63	4547
3	7	3	63	6821
3	7	4	63	9095
3	7	5	63	11369
3	7	6	63	13642
3	7	7	63	15916
3	7	8	63	18190
4	7	2	65	4544
4	7	3	65	6816
4	7	4	65	9089
4	7	5	65	11361
5	7	2	71	4538
5	7	3	71	6807

5	7	4	71	9076
5	7	5	71	11345
1	8	2	60	5050
1	8	3	60	7212
1	8	4	60	9374
1	8	5	60	11536
1	8	6	60	13699
1	8	7	60	15861
1	8	8	60	18023
2	8	2	60	5402
2	8	3	60	7678
2	8	4	60	9954
2	8	5	60	12231
2	8	6	60	14507
2	8	7	60	16783
2	8	8	60	19059
3	8	2	63	5347
3	8	3	63	7621
3	8	4	63	9895
3	8	5	63	12169
3	8	6	63	14442
3	8	7	63	16716
3	8	8	63	18990
4	8	2	66	5294
4	8	3	66	7566
4	8	4	66	9839
4	8	5	66	12111
5	8	2	71	5088
5	8	3	71	7357
5	8	4	71	9626
5	8	5	71	11895
1	9	1	38	1082
1	9	2	38	2106
1	9	3	38	3074
1	9	4	38	4098
2	9	1	40	1160
2	9	2	40	2258
2	9	3	40	3295
2	9	4	40	4395
3	9	1	43	1148
3	9	2	43	2235

3	9	3	43	3262
3	9	4	43	4349
4	9	1	50	1136
4	9	2	50	2212
4	9	3	50	3228
4	9	4	50	4304
5	9	1	62	1110
5	9	2	62	2163
5	9	3	62	3156
5	9	4	62	4209
1	10	1	22	892
1	10	2	22	1738
1	10	3	22	2536
1	10	4	22	3380
1	10	5	22	4226
2	10	1	35	883
2	10	2	35	1719
2	10	3	35	2509
2	10	4	35	3346
2	10	5	35	4182
3	10	1	40	873
3	10	2	40	1701
3	10	3	40	2483
3	10	4	40	3311
3	10	5	40	4139
4	10	1	46	864
4	10	2	46	1684
4	10	3	46	2456
4	10	4	46	3276
4	10	5	46	4095
5	10	1	60	814
5	10	2	60	1585
5	10	3	60	2313
5	10	4	60	3084
5	10	5	60	3855
1	11	1	22	783
1	11	2	22	1505
1	11	3	22	2174
1	11	4	22	2865
2	11	1	35	815
2	11	2	35	1566

2	11	3	35	2262
2	11	4	35	2982
3	11	1	40	807
3	11	2	40	1551
3	11	3	40	2242
3	11	4	40	2955
4	11	1	46	800
4	11	2	46	1537
4	11	3	46	2221
4	11	4	46	2925
5	11	1	60	752
5	11	2	60	1447
5	11	3	60	2091
5	11	4	60	2758
1	12	1	22	803
1	12	2	22	1563
1	12	3	22	2282
1	12	4	22	3043
2	12	1	35	857
2	12	2	35	1668
2	12	3	35	2434
2	12	4	35	3246
3	12	1	39	848
3	12	2	39	1650
3	12	3	39	2409
3	12	4	39	3212
4	12	1	43	839
4	12	2	43	1633
4	12	3	43	2384
4	12	4	43	3177
5	12	1	55	789
5	12	2	55	1538
5	12	3	55	2244
5	12	4	55	2991
1	13	1	22	744
1	13	2	22	1430
1	13	3	22	2064
1	13	4	22	2722
2	13	1	34	799
2	13	2	34	1536
2	13	3	34	2219

2	13	4	34	2925
3	13	1	38	791
3	13	2	38	1523
3	13	3	38	2199
3	13	4	38	2896
4	13	1	42	784
4	13	2	42	1507
4	13	3	42	2178
4	13	4	42	2870
5	13	1	54	762
5	13	2	54	1465
5	13	3	54	2117
5	13	4	54	2790
1	19	1	22	992
1	19	2	22	1975
1	19	3	22	2947
1	19	4	22	3908
1	19	5	22	4861
2	19	1	35	992
2	19	2	35	1975
2	19	3	35	2947
2	19	4	35	3908
2	19	5	35	4861
3	19	1	40	992
3	19	2	40	1975
3	19	3	40	2947
3	19	4	40	3908
3	19	5	40	4861
4	19	1	46	992
4	19	2	46	1975
4	19	3	46	2947
4	19	4	46	3908
4	19	5	46	4861
5	19	1	60	954
5	19	2	60	1899
5	19	3	60	2834
5	19	4	60	3759
5	19	5	60	4684
1	14	1	18	818
1	14	2	24	1635
1	14	3	24	2396

1	14	4	24	3118
1	14	5	24	3897
1	14	6	24	4676
1	14	7	24	5455
1	14	8	24	6235
2	14	1	36	826
2	14	2	37	1652
2	14	3	37	2420
2	14	4	37	3149
2	14	5	37	3936
2	14	6	37	4723
2	14	7	37	5510
2	14	8	37	6298
3	14	2	42	1637
3	14	3	42	2397
3	14	4	42	3120
3	14	5	42	3899
3	14	6	42	4679
3	14	7	42	5460
3	14	8	42	6239
4	14	2	48	1621
4	14	3	48	2374
4	14	4	48	3090
4	14	5	48	3863
4	14	6	48	4635
4	14	7	48	5408
4	14	8	48	6180
5	14	2	62	1524
5	14	3	62	2232
5	14	4	62	2905
5	14	5	62	3630
5	14	6	62	4356
5	14	7	62	5083
5	14	8	62	5809
1	15	1	24	818
1	15	2	24	1635
1	15	3	24	2396
1	15	4	24	3118
1	15	5	24	3897
1	15	6	24	4676
1	15	7	24	5455

1	15	8	24	6235
2	15	1	37	826
2	15	2	37	1652
2	15	3	37	2420
2	15	4	37	3149
2	15	5	37	3936
2	15	6	37	4723
2	15	7	37	5510
2	15	8	37	6298
3	15	1	42	818
3	15	2	42	1637
3	15	3	42	2397
3	15	4	42	3120
3	15	5	42	3899
3	15	6	42	4679
3	15	7	42	5460
3	15	8	42	6239
4	15	1	48	811
4	15	2	48	1621
4	15	3	48	2374
4	15	4	48	3090
4	15	5	48	3863
4	15	6	48	4635
4	15	7	48	5408
4	15	8	48	6180
5	15	1	62	762
5	15	2	62	1524
5	15	3	62	2232
5	15	4	62	2905
5	15	5	62	3630
5	15	6	62	4356
5	15	7	62	5083
5	15	8	62	5809
1	16	1	21	744
1	16	2	21	1430
1	16	3	21	2064
1	16	4	21	2722
1	16	5	21	3167
2	16	1	34	776
2	16	2	34	1492
2	16	3	34	2154

2	16	4	34	2839
3	16	1	38	768
3	16	2	38	1479
3	16	3	38	2134
3	16	4	38	2812
4	16	1	41	761
4	16	2	41	1463
4	16	3	41	2115
4	16	4	41	2786
5	16	1	53	740
5	16	2	53	1422
5	16	3	53	2055
5	16	4	53	2708
1	17	1	20	563
1	17	2	20	1046
1	17	3	20	1551
1	17	4	20	2181
2	17	1	30	590
2	17	2	30	1097
2	17	3	30	1612
2	17	4	30	2268
3	17	1	36	589
3	17	2	36	1094
3	17	3	36	1612
3	17	4	36	2268
4	17	1	40	589
4	17	2	40	1094
4	17	3	40	1612
4	17	4	40	2268
5	17	1	49	553
5	17	2	49	1030
5	17	3	49	1515
5	17	4	49	2124
1	18	1	16	350
2	18	1	16	350
3	18	1	16	350
4	18	1	16	350
5	18	1	16	350
1	20	1	58	1500
1	20	2	58	3000
1	20	3	58	4500

1	20	4	58	6000
2	20	1	58	1500
2	20	2	58	3000
2	20	3	58	4500
2	20	4	58	6000
3	20	1	61	1500
3	20	2	61	3000
3	20	3	61	4500
3	20	4	61	6000
4	20	1	64	1500
4	20	2	64	3000
4	20	3	64	4500
4	20	4	64	6000
5	20	1	70	1500
5	20	2	70	3000
5	20	3	70	4500
5	20	4	70	6000
1	21	1	13	1500
1	21	2	13	3000
2	21	1	13	1500
2	21	2	13	3000
3	21	1	13	1500
3	21	2	13	3000
4	21	1	13	1500
4	21	2	13	3000
5	21	1	13	1500
5	21	2	13	3000
1	26	1	13	1500
1	26	2	13	3000
2	26	1	13	1500
2	26	2	13	3000
3	26	1	13	1500
3	26	2	13	3000
4	26	1	13	1500
4	26	2	13	3000
5	26	1	13	1500
5	26	2	13	3000
1	27	1	58	1500
1	27	2	58	3000
1	27	3	58	4500
1	27	4	58	6000

2	27	1	58	1500
2	27	2	58	3000
2	27	3	58	4500
2	27	4	58	6000
3	27	1	61	1500
3	27	2	61	3000
3	27	3	61	4500
3	27	4	61	6000
4	27	1	64	1500
4	27	2	64	3000
4	27	3	64	4500
4	27	4	64	6000
5	27	1	70	1500
5	27	2	70	3000
5	27	3	70	4500
5	27	4	70	6000
1	29	1	33	1500
1	29	2	33	3000
2	29	1	33	1500
2	29	2	33	3000
3	29	1	58	1500
3	29	2	58	3000
4	29	1	58	1500
4	29	2	58	3000
5	29	1	58	1500
5	29	2	58	3000
1	30	1	18	0
1	30	1	18	0
1	30	2	18	0
1	30	3	18	0
1	30	4	18	0
2	30	1	33	0
2	30	1	33	0
2	30	2	33	0
2	30	3	33	0
2	30	4	33	0
3	30	1	33	0
3	30	1	33	0
3	30	2	33	0
3	30	3	33	0
3	30	4	33	0

4	30	1	33	0
4	30	1	33	0
4	30	2	33	0
4	30	3	33	0
4	30	4	33	0
5	30	1	33	0
5	30	1	33	0
5	30	2	33	0
5	30	3	33	0
5	30	4	33	0
1	31	1	18	0
1	31	1	18	0
1	31	2	18	0
1	31	3	18	0
1	31	4	18	0
2	31	1	33	0
2	31	1	33	0
2	31	2	33	0
2	31	3	33	0
2	31	4	33	0
3	31	1	33	0
3	31	1	33	0
3	31	2	33	0
3	31	3	33	0
3	31	4	33	0
4	31	1	33	0
4	31	1	33	0
4	31	2	33	0
4	31	3	33	0
4	31	4	33	0
5	31	1	33	0
5	31	1	33	0
5	31	2	33	0
5	31	3	33	0
5	31	4	33	0
1	40	1	58	1500
1	40	2	58	3000
1	40	3	58	4500
1	40	4	58	6000
2	40	1	58	1500
2	40	2	58	3000

2	40	3	58	4500
2	40	4	58	6000
3	40	1	61	1500
3	40	2	61	3000
3	40	3	61	4500
3	40	4	61	6000
4	40	1	64	1500
4	40	2	64	3000
4	40	3	64	4500
4	40	4	64	6000
5	40	1	70	1500
5	40	2	70	3000
5	40	3	70	4500
5	40	4	70	6000
1	41	1	13	1500
1	41	2	13	3000
2	41	1	13	1500
2	41	2	13	3000
3	41	1	13	1500
3	41	2	13	3000
4	41	1	13	1500
4	41	2	13	3000
5	41	1	13	1500
5	41	2	13	3000
1	47	1	58	1500
1	47	2	58	3000
1	47	3	58	4500
1	47	4	58	6000
2	47	1	58	1500
2	47	2	58	3000
2	47	3	58	4500
2	47	4	58	6000
3	47	1	61	1500
3	47	2	61	3000
3	47	3	61	4500
3	47	4	61	6000
4	47	1	64	1500
4	47	2	64	3000
4	47	3	64	4500
4	47	4	64	6000
5	47	1	70	1500

5	47	2	70	3000
5	47	3	70	4500
5	47	4	70	6000
1	49	1	33	1500
1	49	2	33	3000
2	49	1	33	1500
2	49	2	33	3000
3	49	1	58	1500
3	49	2	58	3000
4	49	1	58	1500
4	49	2	58	3000
5	49	1	58	1500
5	49	2	58	3000
1	50	1	25	787
1	50	2	25	1527
1	50	3	25	2088
1	50	4	25	2694
2	50	1	37	827
2	50	2	37	1606
2	50	3	37	2196
2	50	4	37	2834
3	50	1	42	819
3	50	2	42	1590
3	50	3	42	2173
3	50	4	42	2804
4	50	1	46	810
4	50	2	46	1573
4	50	3	46	2150
4	50	4	46	2774
5	50	1	52	768
5	50	2	52	1491
5	50	3	52	2035
5	50	4	52	2623
1	51	1	22	751
1	51	2	22	1458
1	51	3	22	2021
1	51	4	22	2605
2	51	1	38	790
2	51	2	38	1533
2	51	3	38	2125
2	51	4	38	2740

3	51	1	43	782
3	51	2	43	1518
3	51	3	43	2103
3	51	4	43	2711
4	51	1	48	773
4	51	2	48	1502
4	51	3	48	2081
4	51	4	48	2682
5	51	1	55	732
5	51	2	55	1422
5	51	3	55	1967
5	51	4	55	2533
1	52	1	22	1372
2	52	1	35	1444
3	52	1	39	1444
4	52	1	43	1425
5	52	1	55	1397
1	52	2	22	2744
2	52	2	35	2889
3	52	2	39	2889
4	52	2	43	2850
5	52	2	55	2794
1	52	3	22	2196
2	52	3	35	4332
3	52	3	39	4332
4	52	3	43	4275
5	52	3	55	4191
1	53	1	49	1372
1	53	2	49	2744
1	53	3	49	4117
1	53	4	49	5489
1	53	5	49	6861
1	53	6	49	8233
2	53	1	49	1444
2	53	2	49	2889
2	53	3	49	4333
2	53	4	49	5778
2	53	5	49	7222
2	53	6	49	8667
3	53	1	54	1444
3	53	2	54	2889

3	53	3	54	4333
3	53	4	54	5778
3	53	5	54	7222
3	53	6	54	8667
4	53	1	54	1425
4	53	2	54	2850
4	53	3	54	4276
4	53	4	54	5701
5	53	1	54	1397
5	53	2	54	2794
5	53	3	54	4192
5	53	4	54	5589
1	60	1	58	1500
1	60	2	58	3000
1	60	3	58	4500
1	60	4	58	6000
2	60	1	58	1500
2	60	2	58	3000
2	60	3	58	4500
2	60	4	58	6000
3	60	1	61	1500
3	60	2	61	3000
3	60	3	61	4500
3	60	4	61	6000
4	60	1	64	1500
4	60	2	64	3000
4	60	3	64	4500
4	60	4	64	6000
5	60	1	70	1500
5	60	2	70	3000
5	60	3	70	4500
5	60	4	70	6000
1	80	1	58	1500
1	80	2	58	3000
1	80	3	58	4500
1	80	4	58	6000
2	80	1	58	1500
2	80	2	58	3000
2	80	3	58	4500
2	80	4	58	6000
3	80	1	61	1500

3	80	2	61	3000
3	80	3	61	4500
3	80	4	61	6000
4	80	1	64	1500
4	80	2	64	3000
4	80	3	64	4500
4	80	4	64	6000
5	80	1	70	1500
5	80	2	70	3000
5	80	3	70	4500
5	80	4	70	6000
1	90	1	20	1025
1	90	2	20	1998
1	90	3	20	2918
1	90	4	20	3891
1	90	5	20	4864
1	90	6	20	5837
2	90	1	34	1014
2	90	2	34	1978
2	90	3	34	2889
2	90	4	34	3851
2	90	5	34	4814
2	90	6	34	5777
3	90	1	39	1004
3	90	2	39	1957
3	90	3	39	2859
3	90	4	39	3811
3	90	5	39	4764
3	90	6	39	5716
4	90	1	43	976
4	90	2	43	1902
4	90	3	43	2777
4	90	4	43	3703
4	90	5	43	4629
4	90	6	43	5555
5	90	1	59	919
5	90	2	59	1790
5	90	3	59	2615
5	90	4	59	3486
5	90	5	59	4358
5	90	6	59	5229

1	91	1	28	1082
1	91	2	28	2106
1	91	3	28	3074
1	91	4	28	4098
2	91	1	36	1204
2	91	2	36	2345
2	91	3	36	3422
2	91	4	36	4563
2	91	5	36	5704
2	91	6	36	6845
3	91	1	42	1192
3	91	2	42	2321
3	91	3	42	3387
3	91	4	42	4517
3	91	5	42	5646
3	91	6	42	6775
4	91	1	46	1136
4	91	2	46	2212
4	91	3	46	3228
4	91	4	46	4304
4	91	5	46	5380
4	91	6	46	6456
5	91	1	60	1053
5	91	2	60	2050
5	91	3	60	2992
5	91	4	60	3991
5	91	5	60	4988
5	91	6	60	5986

APPENDIX B
CENTROID CONNECTOR SPEEDS

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

APPENDIX C
CALIBRATED F-FACTORS

Table C.1 Calibrated F-Factors by Trip Purpose

Time (minutes)	Friction Factors						
	HBW INC Grp 1	HBW INC Grp 2	HBW INC Grp 3	HBW INC Grp 4	HBW INC Grp 5	TAXI	EXTL-AUTO
1	514.107239	300.104889	370.151245	445.572296	354.442932	335.937012	16.33280
2	306.287262	220.568985	230.202805	279.981201	235.521912	243.877350	14.71530
3	192.856873	168.121124	178.120636	186.197495	181.918854	169.704163	13.82830
4	132.788635	119.599823	124.445091	129.675140	123.478600	125.163979	13.05260
5	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000	12.03020
6	85.250519	85.024261	84.867577	85.070686	82.215347	79.335503	10.84530
7	73.432091	71.904449	70.043053	74.684296	66.251434	61.867062	9.62330
8	63.034725	57.979973	59.008663	64.571846	55.958069	49.127468	8.65170
9	50.688385	46.232933	47.679382	53.734589	47.390850	38.809814	7.91070
10	41.818012	37.325356	39.187550	44.142754	41.289719	30.511103	7.31400
11	34.579052	30.280441	32.454174	36.437248	35.765347	23.572901	6.63570
12	28.125746	24.890846	26.761078	29.676039	30.844599	17.726925	5.95670
13	22.309353	20.662556	22.514578	24.332315	25.320972	14.164465	5.28220
14	18.741444	17.436695	19.138865	19.856064	20.785559	11.044847	4.69610
15	15.742883	14.627840	16.478493	16.409157	17.060665	9.157674	4.18060
16	13.337146	12.679819	14.308930	13.920365	14.282129	7.697894	3.73510
17	11.417889	11.102739	12.631548	11.880345	12.236019	6.505482	3.34040
18	9.896170	9.858839	11.243273	10.391848	10.553404	5.297529	2.93180
19	8.695370	8.933642	9.924524	9.251200	9.285540	4.611560	2.52100
20	7.707771	8.087455	8.584678	8.288593	8.241692	3.875304	2.23900
21	6.910826	7.445615	7.621731	7.461421	7.049815	3.181346	2.01170
22	6.210604	6.813641	6.669475	6.761466	5.926759	2.621890	1.79820
23	5.578340	6.236336	5.940836	6.077179	5.283240	2.295249	1.59040
24	5.030081	5.729202	5.144917	5.333150	4.777235	2.064678	1.41040
25	4.550843	5.299999	4.696433	4.739078	4.303539	1.775562	1.25300
26	4.122393	4.924005	4.210023	4.347028	3.941275	1.517538	1.12110
27	3.673809	4.548100	3.718811	4.096188	3.601173	1.360569	1.01850
28	3.280088	4.017910	3.430504	3.843037	3.263806	1.275105	0.91520
29	2.965077	3.427183	3.168849	3.621238	2.977132	1.202850	0.80760
30	2.737074	2.917074	2.940913	3.442834	2.772180	1.134224	0.67610
31	2.374777	2.535982	2.758981	3.326613	2.621294	1.076132	0.57000
32	2.104620	2.075618	2.597114	3.215557	2.535018	0.900691	0.50210
33	1.871217	1.773680	2.443243	2.981835	2.308511	0.858513	0.43850
34	1.661875	1.501635	2.161720	2.744602	2.189333	0.773856	0.38750
35	1.523584	1.240555	1.902530	2.425207	2.107499	0.716734	0.33440
36	1.433987	1.131306	1.730449	2.175953	2.043917	0.673185	0.30830
37	1.432254	1.064047	1.634262	1.940141	1.942222	0.560633	0.28490
38	1.346913	1.000774	1.534402	1.726105	1.875986	0.488166	0.25680
39	1.250709	0.944681	1.443648	1.670909	1.828144	0.447025	0.21830
40	1.144014	0.897411	1.362966	1.630437	1.791421	0.412889	0.18940

Table C.1 Calibrated F-Factors by Trip Purpose (continued)

Time (minutes)	Friction Factors						
	HBW INC Grp 1	HBW INC Grp 2	HBW INC Grp 3	HBW INC Grp 4	HBW INC Grp 5	TAXI	EXTL-AUTO
41	1.009359	0.854373	1.289547	1.601708	1.741886	0.385419	0.16580
42	0.953916	0.809050	1.213041	1.561663	1.415470	0.359289	0.15040
43	0.905690	0.768594	0.980946	1.522620	1.329169	0.288531	0.14140
44	0.798066	0.724771	0.872826	1.486092	1.189637	0.263904	0.12920
45	0.720136	0.681058	0.797183	1.265634	1.082717	0.254704	0.11890
46	0.676882	0.637553	0.780443	1.115882	1.006629	0.234200	0.10940
47	0.514829	0.594048	0.770526	0.994327	0.937923	0.213723	0.10080
48	0.460933	0.571862	0.769774	0.943200	0.893920	0.191680	0.09300
49	0.380198	0.547939	0.767185	0.888849	0.850969	0.169627	0.08580
50	0.321426	0.540665	0.692994	0.834918	0.782941	0.141504	0.07920
51	0.285251	0.532084	0.683392	0.814026	0.708793	0.138940	0.07320
52	0.278729	0.525161	0.540082	0.716934	0.629355	0.138302	0.06770
53	0.272515	0.518663	0.441415	0.658773	0.528361	0.136477	0.06260
54	0.266456	0.512019	0.399568	0.598442	0.516506	0.135928	0.05800
55	0.260746	0.505700	0.326771	0.590607	0.491063	0.134579	0.05370
56	0.254595	0.499797	0.319799	0.582753	0.481897	0.133230	0.04980
57	0.248279	0.494975	0.313433	0.575445	0.472540	0.120691	0.04620
58	0.241454	0.491634	0.307329	0.570304	0.467085	0.116486	0.04290
59	0.234766	0.486781	0.301287	0.566958	0.466160	0.115224	0.03990
60	0.228200	0.480834	0.294793	0.543545	0.363812	0.112928	0.03710
61	0.221500	0.474020	0.288237	0.452061	0.315838	0.109584	0.03450
62	0.213715	0.467741	0.244776	0.451797	0.230848	0.104169	0.03220
63	0.204980	0.443370	0.234998	0.450265	0.217721	0.098754	0.03000
64	0.196967	0.418999	0.225158	0.450042	0.205906	0.097245	0.02800
65	0.188686	0.378215	0.215373	0.449922	0.193437	0.095352	0.02610
66	0.179810	0.341759	0.204876	0.449576	0.178997	0.093458	0.02440
67	0.164546	0.266854	0.194199	0.440665	0.166012	0.083998	0.02280
68	0.149345	0.259291	0.182199	0.431754	0.152935	0.083236	0.02130
69	0.131828	0.255573	0.170416	0.422842	0.143575	0.076333	0.01990
70	0.112361	0.250448	0.130595	0.413931	0.142832	0.064940	0.01870
71	0.103523	0.242327	0.123188	0.405020	0.142554	0.029580	0.01750
72	0.072152	0.232775	0.114376	0.327330	0.140945	0.029513	0.01640
73	0.063770	0.223990	0.104982	0.273396	0.139510	0.029159	0.01540
74	0.057381	0.213801	0.095235	0.215953	0.137187	0.028780	0.01450
75	0.055973	0.197449	0.084655	0.142745	0.136155	0.028406	0.01360
76	0.053336	0.153959	0.084012	0.121606	0.135328	0.028037	0.01280
77	0.050451	0.130575	0.083369	0.111245	0.133311	0.027672	0.01210
78	0.047418	0.106075	0.082726	0.102786	0.131379	0.027312	0.01140
79	0.044836	0.079878	0.082083	0.099247	0.130961	0.026957	0.01070
80	0.042734	0.065996	0.081440	0.097028	0.129717	0.026607	0.01010

Table C.1 Calibrated F-Factors by Trip Purpose (continued)

Time (minutes)	Friction Factors						
	HBW INC Grp 1	HBW INC Grp 2	HBW INC Grp 3	HBW INC Grp 4	HBW INC Grp 5	TAXI	EXTL-AUTO
81	0.039950	0.051239	0.080797	0.096396	0.129646	0.026261	0.00950
82	0.036336	0.031808	0.080154	0.096304	0.128984	0.025920	0.00900
83	0.032725	0.030864	0.079511	0.095915	0.128947	0.025583	0.00850
84	0.029122	0.029808	0.078867	0.095242	0.127771	0.025250	0.00810
85	0.025361	0.028419	0.078224	0.093883	0.127015	0.024922	0.00760
86	0.021395	0.027528	0.077581	0.092519	0.126035	0.024598	0.00720
87	0.016944	0.026707	0.076938	0.092296	0.125178	0.024278	0.00690
88	0.011852	0.025627	0.076295	0.092241	0.124613	0.023962	0.00650
89	0.008382	0.024784	0.075652	0.090472	0.121681	0.023651	0.00620
90	0.007963	0.023420	0.075009	0.088387	0.117512	0.023343	0.00590
91	0.007565	0.021091	0.074366	0.086703	0.107409	0.023040	0.00560
92	0.007187	0.018577	0.073853	0.085569	0.096188	0.022740	0.00530
93	0.006827	0.015512	0.073723	0.083480	0.095625	0.022445	0.00500
94	0.006486	0.008330	0.072418	0.081950	0.080740	0.022153	0.00480
95	0.006162	0.006537	0.070829	0.081915	0.079778	0.021865	0.00460
96	0.005853	0.006406	0.069211	0.079388	0.072269	0.021581	0.00440
97	0.005561	0.006278	0.067071	0.078797	0.064702	0.021300	0.00420
98	0.005283	0.006153	0.063795	0.076428	0.061322	0.021023	0.00400
99	0.005019	0.006030	0.060034	0.076189	0.057097	0.020750	0.00380
100	0.004768	0.005909	0.055191	0.074449	0.050493	0.020480	0.00360
101	0.004529	0.005791	0.048275	0.074211	0.045599	0.020214	0.00350
102	0.004303	0.005675	0.039788	0.072436	0.041272	0.019951	0.00330
103	0.004088	0.005561	0.030213	0.071609	0.040102	0.019692	0.00320
104	0.003883	0.005450	0.029609	0.070178	0.036769	0.019436	0.00310
105	0.003689	0.005341	0.029017	0.058303	0.032761	0.019183	0.00300
106	0.003505	0.005234	0.028436	0.046393	0.029683	0.018934	0.00280
107	0.003329	0.005130	0.027868	0.033282	0.029043	0.018688	0.00270
108	0.003163	0.005027	0.027310	0.031951	0.027300	0.018445	0.00260
109	0.003005	0.004927	0.026764	0.030673	0.025082	0.018205	0.00250
110	0.002855	0.004828	0.026229	0.029446	0.023122	0.017968	0.00240
111	0.002712	0.004731	0.025704	0.028268	0.021578	0.017735	0.00000
112	0.002576	0.004637	0.025190	0.027137	0.020076	0.017504	0.00000
113	0.002447	0.004544	0.024686	0.026052	0.018905	0.017277	0.00000
114	0.002325	0.004453	0.024192	0.025010	0.017970	0.017052	0.00000
115	0.002209	0.004364	0.023709	0.024009	0.017083	0.016830	0.00000
116	0.002098	0.004277	0.023234	0.023049	0.016205	0.016612	0.00000
117	0.001993	0.004191	0.022770	0.022127	0.015850	0.016396	0.00000
118	0.001894	0.004108	0.022314	0.021242	0.015191	0.016182	0.00000
119	0.001799	0.004025	0.021868	0.020392	0.013745	0.015972	0.00000
120	0.001709	0.003945	0.021431	0.019577	0.012244	0.015764	0.00000

Table C.2 Calibrated F-Factors by Trip Purpose

Time minutes	Friction Factors					
	HBNW-ED1	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER	NHB Work-Based	NHB Non-Work-Based
1	469.462097	396.883728	0.000000	562.017700	295.210236	305.624634
2	284.392944	200.778961	87.515884	327.053864	235.982910	232.162979
3	186.969406	185.017670	103.387547	207.740067	170.963821	166.626587
4	141.633224	136.119507	102.196688	140.172684	126.372231	123.413063
5	100.000000	100.000000	100.000000	100.000000	100.000000	100.000000
6	74.345695	73.804611	88.092404	75.500290	78.796677	78.235847
7	49.453655	53.676311	81.895695	52.411060	61.455517	60.639755
8	34.069950	38.567181	78.057737	38.918488	48.374268	45.217926
9	22.887098	26.446436	75.192912	27.968241	36.962982	32.551388
10	16.119810	19.446812	73.025317	19.616817	28.202356	24.729874
11	12.914672	15.262584	71.269617	13.958101	21.517532	19.186024
12	10.163768	10.890317	69.917426	10.188935	16.026688	15.107874
13	7.792601	7.390912	68.493847	7.541087	12.758224	11.135723
14	5.925422	5.031461	67.174473	5.545444	10.002880	8.095463
15	4.382248	3.416955	66.249489	4.263978	8.353618	6.192147
16	3.154277	2.473196	65.632922	3.228028	7.090659	5.197272
17	2.314983	1.990000	65.325164	2.505966	6.045355	4.049120
18	1.877343	1.515802	65.335653	1.980964	4.898099	3.306489
19	1.314032	1.172324	65.585737	1.530704	4.205086	2.891359
20	0.860087	0.917079	65.857665	1.215182	3.518345	2.377297
21	0.719853	0.715117	66.429795	1.001605	2.881752	1.838656
22	0.636810	0.566310	67.447927	0.758198	2.401801	1.446853
23	0.475754	0.463087	68.593522	0.618016	2.130441	1.336613
24	0.354828	0.388661	69.729481	0.498777	1.923023	1.237351
25	0.231882	0.287959	70.882529	0.410709	1.652934	1.146532
26	0.185050	0.205142	72.056681	0.324624	1.407567	1.060319
27	0.163165	0.157218	73.152061	0.278007	1.267157	0.908416
28	0.154592	0.135830	74.148709	0.216406	1.202523	0.719788
29	0.146019	0.131128	75.061140	0.168049	1.144792	0.628381
30	0.128617	0.100279	76.062055	0.145819	1.085992	0.582664
31	0.112184	0.068983	77.275217	0.119156	1.032379	0.511801
32	0.098840	0.063520	78.537695	0.088503	0.869380	0.457231
33	0.078870	0.058057	79.812493	0.083254	0.830966	0.433340
34	0.071565	0.051517	81.044389	0.078805	0.754030	0.403769
35	0.064291	0.045518	82.249681	0.074515	0.701297	0.360886
36	0.057597	0.040215	83.358646	0.071137	0.659169	0.293869
37	0.051203	0.035466	84.315136	0.067711	0.548771	0.249212
38	0.045013	0.031214	84.945473	0.064605	0.478638	0.223458
39	0.040481	0.027294	85.441680	0.061608	0.440870	0.209961
40	0.032745	0.023740	84.196208	0.054238	0.409445	0.196660

Table C.2 Calibrated F-Factors by Trip Purpose (continued)

Time (minutes)	Friction Factors					
	HBNW-ED1	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER	NHB Work-Based	NHB Non-Work-Based
41	0.026699	0.020577	81.440391	0.052546	0.384827	0.183662
42	0.022560	0.017677	79.273216	0.051322	0.358941	0.171516
43	0.018570	0.014993	77.964578	0.049855	0.285219	0.159610
44	0.018393	0.012500	76.373724	0.048576	0.260282	0.146833
45	0.018255	0.010220	74.499669	0.047435	0.251296	0.112581
46	0.017111	0.008178	72.337117	0.046205	0.231626	0.110600
47	0.016007	0.007044	69.851811	0.040923	0.210955	0.107791
48	0.014976	0.006404	67.012252	0.035825	0.189136	0.101245
49	0.013934	0.005850	63.689478	0.034041	0.166742	0.094451
50	0.012890	0.005361	59.922367	0.024071	0.138171	0.087270
51	0.011879	0.004901	56.010088	0.023426	0.136365	0.079968
52	0.010914	0.004471	52.061729	0.017362	0.135906	0.072718
53	0.009952	0.004057	48.126050	0.014841	0.135446	0.065358
54	0.008955	0.003666	44.186568	0.014601	0.135245	0.057846
55	0.007932	0.003315	40.304343	0.014242	0.127482	0.043458
56	0.006489	0.002995	36.527204	0.013998	0.122282	0.041702
57	0.005016	0.002701	32.943757	0.013754	0.117081	0.039768
58	0.003025	0.002411	29.464133	0.012872	0.112812	0.037630
59	0.001168	0.002119	26.157653	0.011870	0.107677	0.035331
60	0.001021	0.001839	23.170085	0.010862	0.107582	0.033024
61	0.000957	0.001581	20.494271	0.009963	0.105592	0.030522
62	0.000872	0.001519	18.024145	0.009043	0.093009	0.027813
63	0.000790	0.001321	15.735575	0.008061	0.092397	0.025181
64	0.000726	0.001202	13.628221	0.006996	0.090187	0.022389
65	0.000641	0.001085	11.730859	0.006943	0.089765	0.019433
66	0.000629	0.000976	10.074825	0.006932	0.085669	0.016517
67	0.000620	0.000873	8.610077	0.006837	0.076712	0.013447
68	0.000612	0.000778	7.325028	0.006814	0.076303	0.009746
69	0.000606	0.000682	6.174787	0.006792	0.066875	0.009683
70	0.000603	0.000589	5.208608	0.006769	0.057446	0.009148
71	0.000596	0.000565	4.357188	0.006582	0.026013	0.008792
72	0.000581	0.000542	3.629540	0.006550	0.026011	0.008386
73	0.000563	0.000520	3.009840	0.006493	0.025800	0.007930
74	0.000554	0.000504	2.461677	0.006476	0.025599	0.007432
75	0.000547	0.000488	1.993125	0.006409	0.025546	0.006876
76	0.000537	0.000474	1.592617	0.006389	0.025211	0.006332
77	0.000534	0.000462	1.257219	0.006258	0.025137	0.005760
78	0.000523	0.000450	1.003585	0.006133	0.025003	0.005180
79	0.000513	0.000440	0.975874	0.006010	0.024994	0.004596
80	0.000502	0.000438	0.948928	0.005890	0.024958	0.003980

Table C.2 Calibrated F-Factors by Trip Purpose (continued)

Time (minutes)	Friction Factors					
	HBNW-ED1	HBNW-RETAIL	HBNW-AIRPORT	HBNW-OTHER	NHB Work-Based	NHB Non-Work-Based
81	0.000494	0.000424	0.922727	0.005772	0.024907	0.003325
82	0.000483	0.000409	0.897249	0.005657	0.024453	0.003259
83	0.000474	0.000391	0.872474	0.005544	0.024420	0.003193
84	0.000464	0.000372	0.863749	0.005433	0.024407	0.003129
85	0.000456	0.000353	0.855112	0.005324	0.024405	0.003067
86	0.000445	0.000335	0.846561	0.005218	0.024336	0.003006
87	0.000436	0.000314	0.838095	0.005113	0.024303	0.002945
88	0.000428	0.000288	0.829714	0.005011	0.024281	0.002887
89	0.000421	0.000262	0.821417	0.004911	0.024179	0.002829
90	0.000410	0.000230	0.813203	0.004813	0.024152	0.002772
91	0.0000	0.000190	0.805071	0.004716	0.023790	0.002717
92	0.0000	0.000188	0.797020	0.004622	0.023433	0.002662
93	0.0000	0.000186	0.789050	0.004530	0.023081	0.002609
94	0.0000	0.000184	0.781159	0.004439	0.022735	0.002557
95	0.0000	0.000183	0.773348	0.004350	0.022394	0.002506
96	0.0000	0.000181	0.765614	0.004263	0.022058	0.002456
97	0.0000	0.000179	0.757958	0.004178	0.021727	0.002407
98	0.0000	0.000177	0.750379	0.004094	0.021401	0.002358
99	0.0000	0.000175	0.742875	0.004012	0.021080	0.002311
100	0.0000	0.000174	0.735446	0.003932	0.020764	0.002265
101	0.0000	0.000172	0.728092	0.003854	0.020453	0.002220
102	0.0000	0.000170	0.720811	0.003776	0.020146	0.002175
103	0.0000	0.000168	0.713603	0.003701	0.019844	0.002132
104	0.0000	0.000167	0.706467	0.003627	0.019546	0.002089
105	0.0000	0.000165	0.699402	0.003554	0.019253	0.002047
106	0.0000	0.000163	0.692408	0.003483	0.018964	0.002007
107	0.0000	0.000162	0.685484	0.003414	0.018680	0.001966
108	0.0000	0.000160	0.678629	0.003345	0.018399	0.001927
109	0.0000	0.000159	0.671843	0.003278	0.018123	0.001889
110	0.0000	0.000157	0.665124	0.003213	0.017852	0.001851
111	0.0000	0.000155	0.658473	0.003149	0.017584	0.001814
112	0.0000	0.000154	0.651888	0.003086	0.017320	0.001777
113	0.0000	0.000152	0.645369	0.003024	0.017060	0.001742
114	0.0000	0.000151	0.638916	0.002963	0.016804	0.001707
115	0.0000	0.000149	0.632527	0.002904	0.016552	0.001673
116	0.0000	0.000148	0.626201	0.002846	0.016304	0.001639
117	0.0000	0.000146	0.619939	0.002789	0.016059	0.001607
118	0.0000	0.000145	0.613740	0.002733	0.015819	0.001575
119	0.0000	0.000143	0.607603	0.002679	0.015581	0.001543
120	0.0000	0.000142	0.601527	0.002625	0.015348	0.001512

APPENDIX D

Sector Systems

The travel demand model makes use of a nested system of analysis zones which at its most detailed level is the 5,519 traffic analysis zones. It is composed of 5,113 internal zones and 46 external stations.

The next level of the nested zone structure is the sector system. A sector is a group of neighboring TAZs aggregated together as a single analysis unit. There are three different sector systems for general trip purpose, home-based work trip purpose, and the home-based school trip purpose. The sector structure serves two main purposes for travel demand process. Primarly, the sector structure provides a means to summarize various travel model results. It also facilitiaties the application of any bais factors which might prove necessary in the application of the trip distribution model.

The number of sectors in the general sector structure increases from 47 sectors in previous version to 51 sectors in this version of travel demand model. The previous 47 sectors were created for year 1985 validation. Even though the previously 47 sector structure served well, as the 8-county region growing rapidly, there is a need to modify the sector strcture to reflect the demographic shift and new infrastructure. The new 51 sectors are derived from the old 47 sectors. Some of the sector boundaries are re-aligned to major factilities built after 1985, particulary along Sam Houston Tollway. Four of the 47 sectors are spilt because the four sectors have substantially large amout of population and employment, bringing the total number of sectors to 51. Figure D.1 shows the new 51 sector system.

A special sector structure was created for HBW person trip table because of its distinct nature. HBW trips are significantly longer than the HBNW and NHB trips, and they have a higher percentage of transit usage. The HBW sector strcture provides greater detail with the 8-county region than the general 51 sector strcture with the addition of seven seven sectors. The additional HBW sectors are developed to separate pockets of major regional employment centers from adjacent residential or mixed-use areas within the same general sector. Figure D.2 shows the 58 HBW sector system.

The third sector structure represents the existing school districts. A high intra-sector bias factor is added to the trip distribution model to encourage HB-ED1 trips travel within the same school district of their home. Without the high intra-sector bias factor, the trip disbution model would assign too many cross-school district HB-ED1 trips. Figure D.3 shows the school district boundary.

Figure D-0-1 General Purpose Sectors

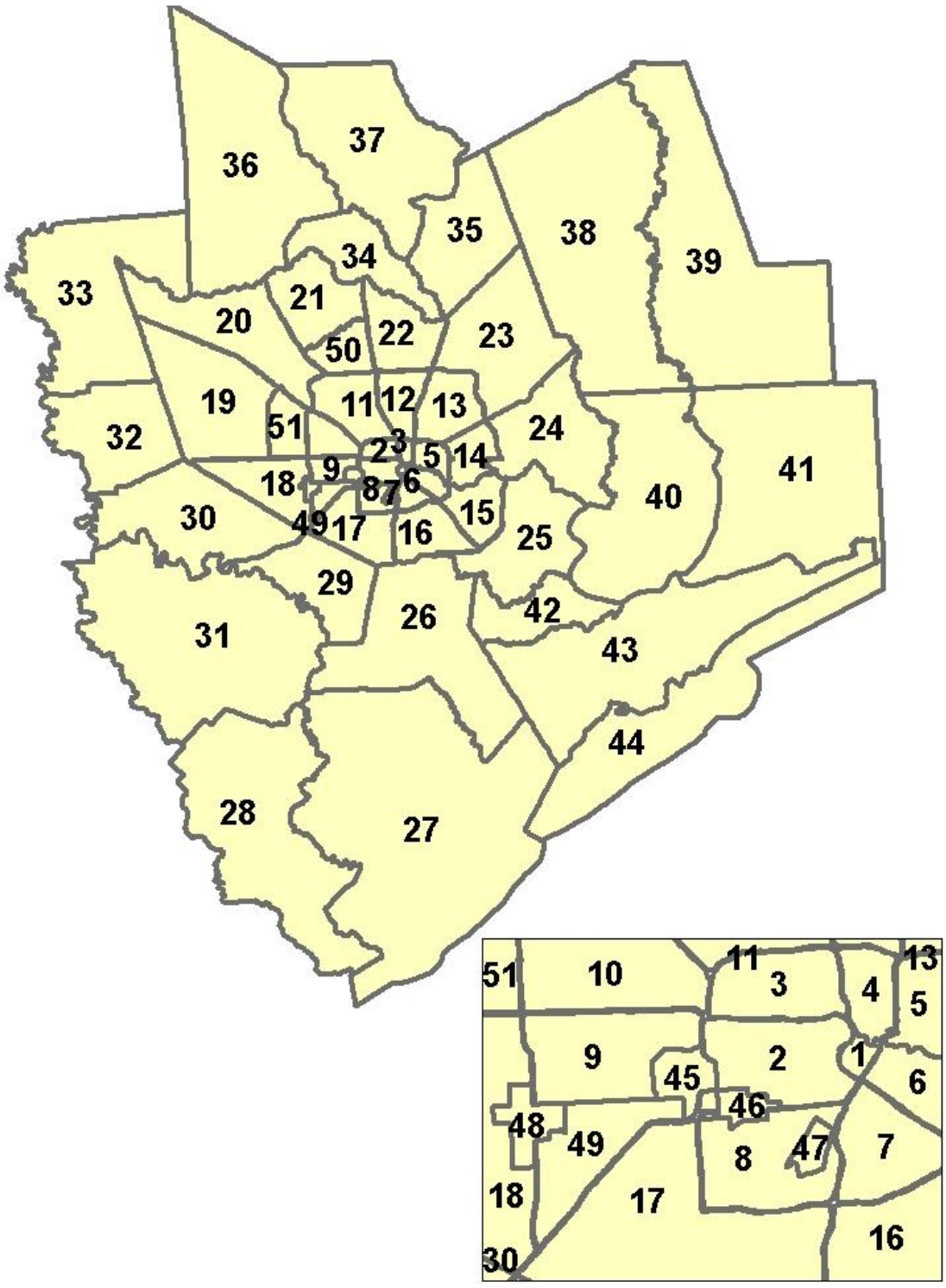


Figure D-0-2 Journey to Work (HBW) Purpose Sectors

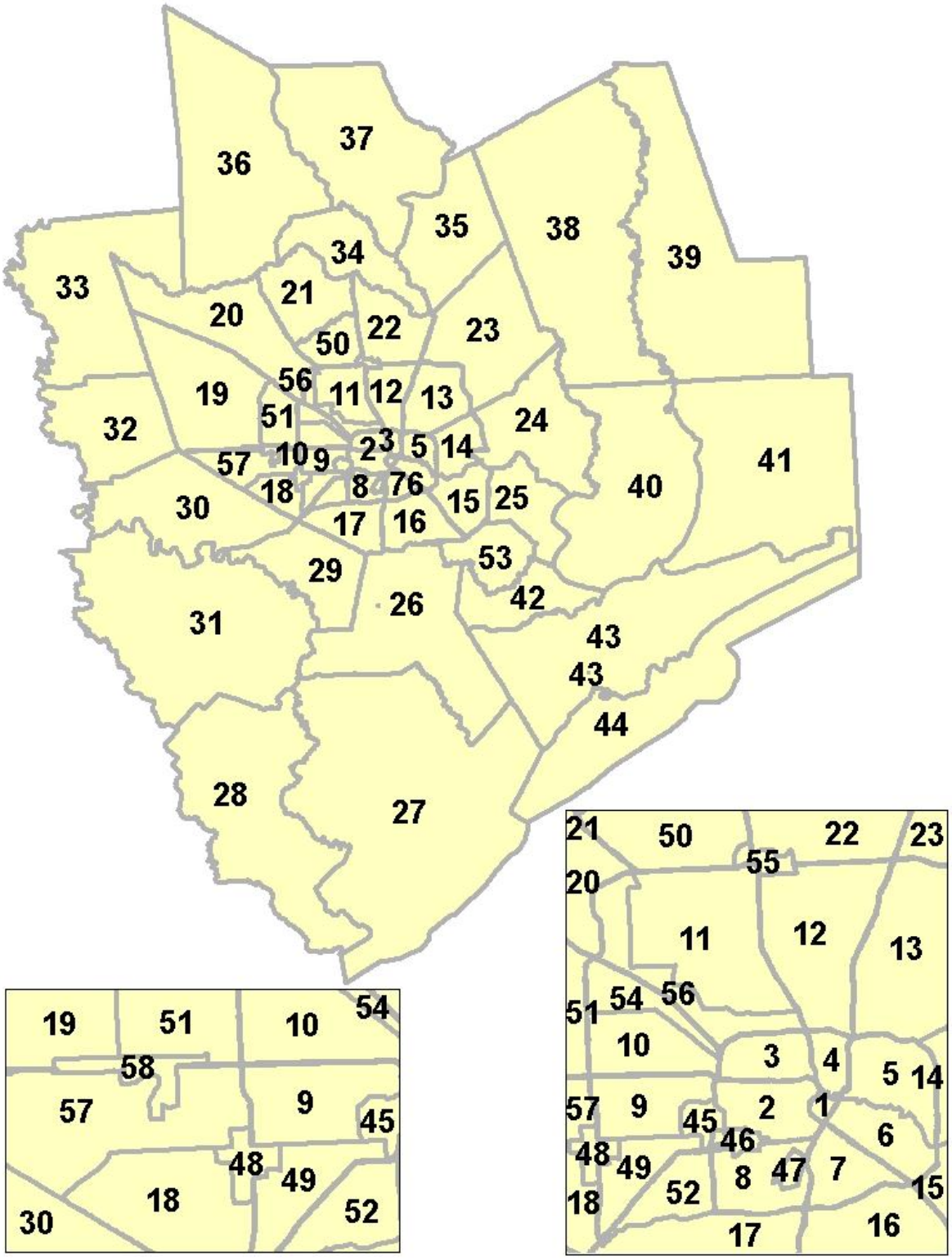
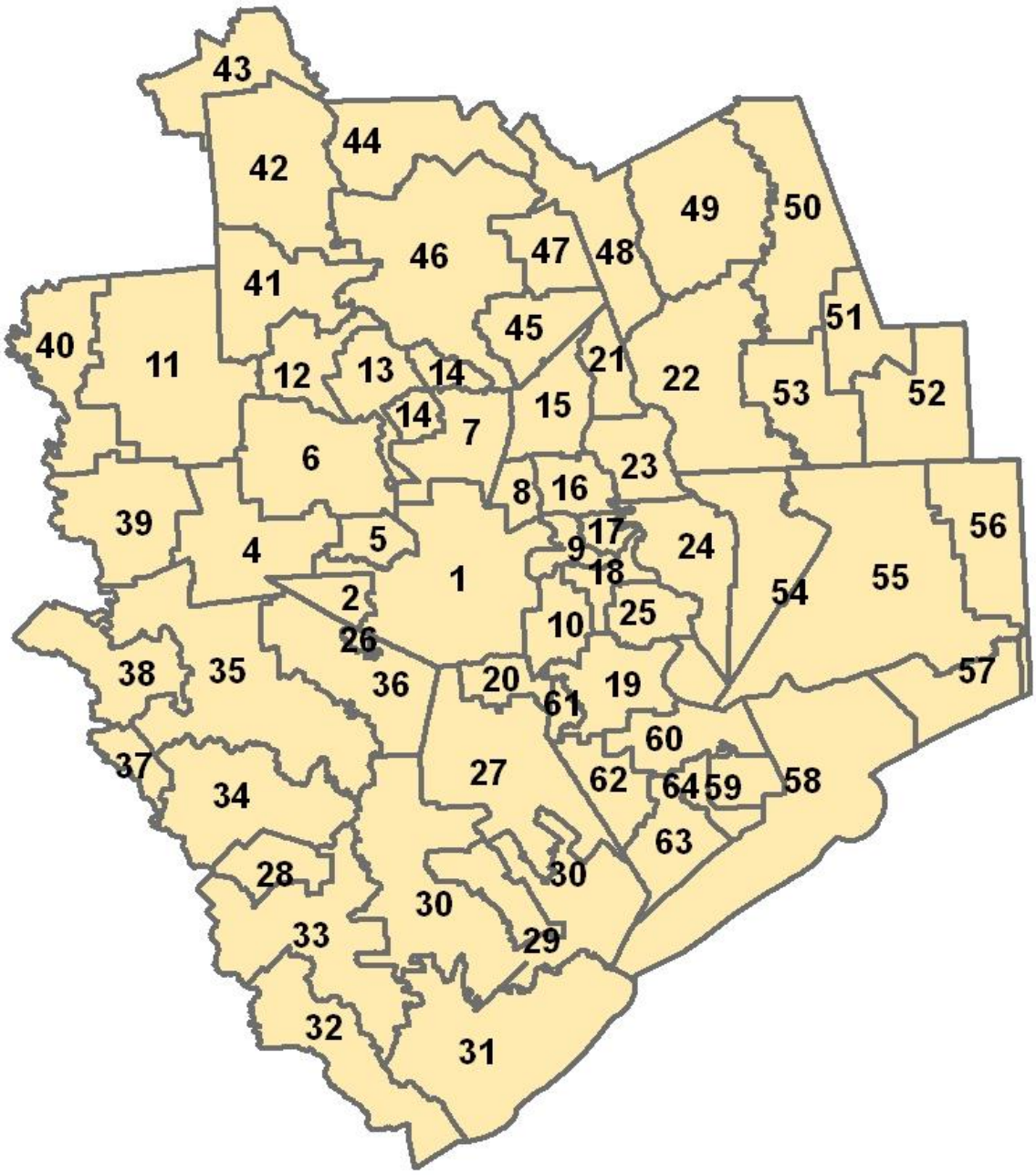


Figure D-3 School Districts Inside 8-County Region



Source: H-GAC

Table D.0.1 List of School Districts Inside 8-County Region

ID	Name
1	Houston Independent School District
2	Alief Independent School District
3	(Not used)
4	Katy Independent School District
5	Spring Branch Independent School District
6	Cypress-Fairbanks Independent School District
7	Aldine Independent School District
8	North Forest Independent School District
9	Galena Park Independent School District
10	Pasadena Independent School District
11	Waller Independent School District
12	Tomball Independent School District
13	Klein Independent School District
14	Spring Independent School District
15	Humble Independent School District
16	Sheldon Independent School District
17	Channelview Independent School District
18	Deer Park Independent School District
19	Clear Creek Independent School District
20	Pearland Independent School District
21	Huffman Independent School District
22	Dayton Independent School District
23	Crosby Independent School District
24	Goose Creek Consolidated Independent School District
25	La Porte Independent School District
26	Stafford Municipal School District
27	Alvin Independent School District
28	Damon Independent School District
29	Danbury Independent School District
30	Angleton Independent School District
31	Brazosport Independent School District
32	Sweeny Independent School District
33	Columbia-Brazoria Independent School District
34	Needville Independent School District
35	Lamar Consolidated Independent School District
36	Fort Bend Independent School District
37	Kendleton Independent School District
38	Brazos Independent School District
39	Royal Independent School District

40	Hempstead Independent School District
41	Magnolia Independent School District
42	Montgomery Independent School District
43	Richards Independent School District
44	Willis Independent School District
45	New Caney Independent School District
46	Conroe Independent School District
47	Splendora Independent School District
48	Cleveland Independent School District
49	Tarkington Independent School District
50	Hardin Independent School District
51	Hull-Daisetta Independent School District
52	Devers Independent School District
53	Liberty Independent School District
54	Barbers Hill Independent School District
55	Anahuac Independent School District
56	East Chambers Independent School District
57	High Island Independent School District
58	Galveston Independent School District
59	Texas City Independent School District
60	Dickinson Independent School District
61	Friendswood Independent School District
62	Santa Fe Independent School District
63	Hitchcock Independent School District
64	La Marque Independent School District

Source: H-GAC