Appendix 3

2009 Travel Model Validation

HOUSTON-GALVESTON AREA COUNCIL
REGIONAL TRAVEL MODELS

2009 Model Validation and Documentation Report

April 2013

1.0 Introduction

The Houston-Galveston Regional Travel Models are cooperatively developed and maintained by the Houston-Galveston Area Council (H-GAC), the Texas Department of Transportation (TxDOT) and the Metropolitan Transit Authority (METRO). This report documents the validation of the Houston-Galveston Regional "Cube Voyager" Travel Models to the Base Year 2009. The Cube Voyager model set is a new standard practice set of travel models that represent a conversion and update to the enhanced H-GAC Travel Models – referred to as the "Track-1" model set. The new Cube Voyager model set is essentially a conversion and enhancement to the Track-1 model set based on 1995 travel survey data for the region. The Track-1 model set is enhanced from the original H-GAC Travel Models – referred to as the "Track-0" model set. This report does not fully document the various model set components, but instead, documents those components that were addressed as part of the 2009 validation. The development of the "Track-1" model set and "Track-0" model set is documented in the following reports.

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

More information about the development and validation of the 'Track-1" Travel Models is documented from another report, titled "H-GAC Travel Model 2009 Validation Report".

1.1 Report Structure

Chapter 2 of the report discusses the development of land use, demographic and cost data for the Base Year 2009. Included in this section is also a discussion and depiction of the zone system used in the H-GAC modeling efforts. Chapter 3 outlines the development of both highway and transit networks. This is followed in Chapter 4 with a discussion of travel forecasting procedures employed in the 1995 validation. The 2009 highway assignment validation results are also summarized in Chapter 4. Chapter 5 discusses the development of an HPMS adjustment factor used in applications of travel model forecasts for air quality conformity and SIP development.

2.0 Land Use, Demographic & Cost Data Development

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

2.1 Zone System Definition

Under 2010 (census related) geography, H-GAC has designated 3,000 detailed traffic analysis zones (TAZs) in the Houston-Galveston TMA. This includes 2,954 internal zones and 46 external stations. The internal zones are entirely within the TMA and the external stations are used to capture external-external and external-local trips into and through the TMA.

2.2 Base Year Demographic Estimates

Estimated Year 2009 households and Year 2009 employment were used as the primary demographic inputs for the Year 2009 validation of the travel models. Estimates of 2009 household were derived from reconciling the existing 2009 forecast to the 2010 Census data for the eight county region. As seen in Table 2.1, the existing 2009 household over estimated the number of households by 26,244 or 1.29 percent. The 2009 TAZ level housebold data were adjusted based on the new county and regional household estimates. Definitional changes to employment categories instituted as part of a new demographic forecast resulted in a situation in which future year forecasts of employment that will be used in conjunction this model set would be different than those of the Year 2009 employment data set. For this reason, employment estimates for the year 2003, which have consistent definitions to the future year employment were used in the validation of the Track-1 models. While use of the year 2003 employment results in a over-estimation of trip attractions, the H-GAC trip generation model scales attractions to match productions. Therefore, the total regional trip ends are the same as they would be if actual year 2009 employment was used.

2.3 Comparison of 2000 and 2009 Population/Household and 2009 Employment Estimates by County

Table 2.2 summarizes the household changes between 2000 and 2009. Region wide households increased over 22 percent, from 1,639,402 million in 2000 to nearly 2,006,179 in 2009. Household growth by county ranged from a low of 5.47 percent (Liberty County) to a high of 65.34 percent (Fort Bend County). Table 2.3 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 2.1
Households of Existing 2009 Forecast
and Reconciled 2009 Household Estimate

County	2009 Existing	2009 Reconciled	Change from 2000	% Change
Harris	1,434,323	1,403,264	-31,059	-2.17%
Brazoria	106,390	104,208	-2,182	-2.05%
Fort Bend	167,610	183,386	15,776	-9.41%
Waller	14,495	13,634	-861	-5.94%
Montgomery	156,103	158,928	2,825	-1.81%
Liberty	29,130	24,513	-4,617	-15.85%
Chambers	12,240	11,692	-548	-4.48%
Galveston	112,132	106,554	-5,578	-4.97%
Total	2,032,423	2,006,179	-26,244	-1.29%

Source: Trip Generation Data for 2009 prepared by H-GAC

Table 2.2
County Households for 2000 and 2009

County	2000	2009	Change from 2000	% Change
Harris	1,205,516	1,403,264	197,748	16.40%
Brazoria	81,954	104,208	22,254	27.15%
Fort Bend	110,915	183,386	72,471	65.34%
Waller	10,557	13,634	3,077	29.15%
Montgomery	103,297	158,928	55,631	53.86%
Liberty	23,242	24,513	1,271	5.47%
Chambers	9,139	11,692	2,553	27.94%
Galveston	94,782	106,554	11,772	12.42%
Total	1,639,402	2,006,179	366,777	22.37%

Source: Trip Generation Data for 1995 and 2009 prepared by H-GAC

Table 2.3
County Household Population for 1995 and 2009

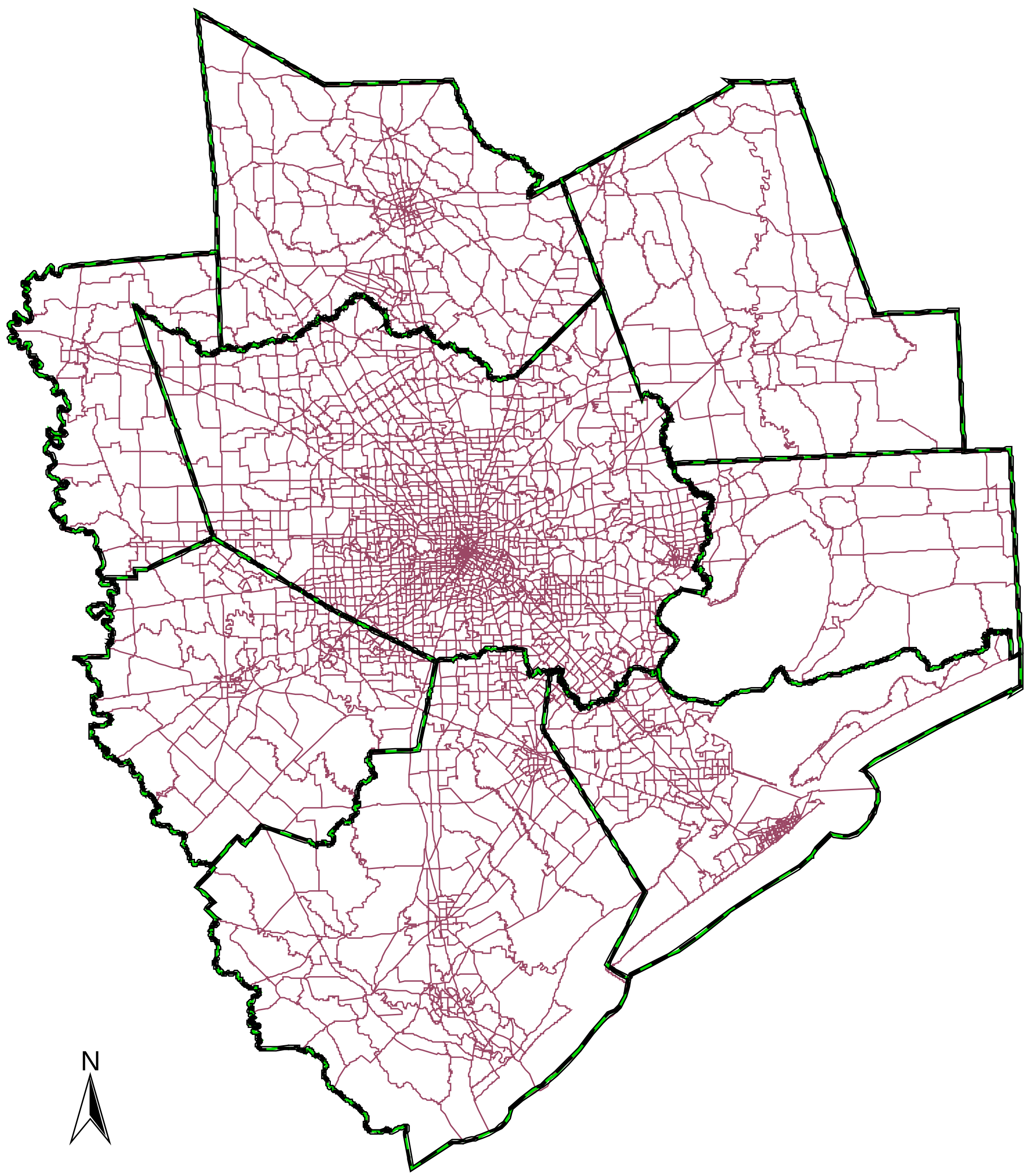
County	2000	2009	Change from 2000	% Change
Harris	3,358,444	3,953,658	595,214	17.72%
Brazoria	230,806	295,520	64,714	28.04%
Fort Bend	348,154	566,439	218,285	62.70%
Waller	29,454	38,347	8,893	30.19%
Montgomery	292,077	442,008	149,931	51.33%
Liberty	65,113	68,854	3,741	5.75%
Chambers	25,797	34,065	8,268	32.05%
Galveston	246,002	280,344	34,342	13.96%
Total	4,595,847	5,679,235	1,083,388	23.57%

Source: Trip Generation Data for 1995 and 2009 prepared by H-GAC


MONTGOMERY
LIBERTY
WALLER
HARRIS
CHAMBERS
FORT BEND
GALVESTON
BRAZORIA
N

Source: H-GAC

Figure 2.2
H-GAC Zone Structure



Source: H-GAC

Employment for the eight county region increased comparably with population growth, 26.59% percent overall (Table 2.4). Harris County gained over 415,068 additional jobs (a 23.03% percent increase), while Fort Bend County employment grew more than 61.39% percent (over 59,126 jobs).

Table 2.4
County Employment for 2000 and 2009

County	2000 Employment	2009 Employment	Change from 2000	% Change
Brazoria	75,556	98,909	23,353	30.91%
Chambers	7,759	8,598	839	10.81%
Fort Bend	96,316	155,442	59,126	61.39%
Galveston	86,469	114,895	28,426	32.87%
Harris	1,802,351	2,217,419	415,068	23.03%
Liberty	15,484	23,358	7,874	50.85%
Montgomery	84,719	125,261	40,542	47.85%
Waller	9,611	13,668	4,057	42.21%
Total	2,178,265	2,757,549	579,284	26.59%

Source: H-GAC Trip Generation Input Data for 2000 & 2009

2.5 Cost Data

2.5.1 Auto Operating Costs

Auto operating cost is an input to the mode choice model and is used by the model in establishing the costs for the auto-related choice paths available in the roadway network. This cost reflects costs that are assumed be variable costs including gas, oil, tires and maintenance. As part of the 2009 validation, auto operating costs were updated to a year 2009 value. This values was then converted to 1985 dollars to be consistent with the manner in which the mode choice model was calibrated. According to the Bureau of Transportation Statistics (BTS), auto operating cost in 2009 was 11.93 cents per mile. When deflated to 1985 dollars using the Bureau of Labor Statistics (BLS) National CPI data, the year 2009 cost in 1985 dollars is 7.15 cents.

2.5.2 Toll Costs

Toll costs are used in the mode choice model in the development of costs paths for the auto-related modal choices of the mode choice model. For toll facilities that existed in the Year 2009, the toll costs are assigned to the links in the network that represent the locations where the tolls are actually collected. Table 2.5 lists the Year 2009 toll costs in 1985 dollars.

Table 2.5
Year 2009 Toll Costs

Location	2009 Toll Cost 1985 Dollars
Hardy - North Plaza	0.47
Hardy - FM 1960 Ramp	0.41
Hardy - Richey Ramp	0.28
Hardy - Rankin Ramp	0.14
Hardy - South Plaza	0.48
Hardy - Bush IAH Ramp	0.28
Hardy - Greens Road Ramp	0.14
Hardy - Aldine Mail Ramp	0.41
Hardy - Little York Ramp	0.28
Hardy - Tidwell Ramp	0.17
Sam Houston North Plaza	0.48
Sam Houston North - SH 249 Ramp	0.41
Sam Houston North - North Gessner Ramp	0.28
Sam Houston North - Fallbrook Ramp	0.28
Sam Houston Central - West Road Ramp	0.14
Sam Houston Central Plaza	0.48
Sam Houston Central - Clay Road Ramp	0.28
Sam Houston Central - Hammerly Ramp	0.14
Sam Houston Southwest Plaza	0.48
Sam Houston Southwest - South Main (90-A)	0.14
Sam Houston Southwest – Hillcroft	0.19
Sam Houston Southwest - West Fuqua	0.28
Sam Houston Southwest – Almeda	0.41
Sam Houston South Plaza	0.48
Sam Houston South – Deerwood	0.28
Sam Houston South - Briar Forest	0.28
Sam Houston South – Westheimer	0.28
Sam Houston South – Bellaire	0.14
Sam Houston South - Beltway 8	0.19
Sam Houston Southeast Plaza	0.48
Sam Houston Southeast - Cullen	0.14
Sam Houston Southeast – Wayside	0.28
Sam Houston Southeast – Telephone Rd	0.19
Sam Houston Southeast – Monroe	0.14
Sam Houston East Plaza	0.50
Sam Houston East - Fairmont Parkway	0.41
Sam Houston East - Spencer Highway	0.28
Sam Houston East - Red Bluff	0.14

Fort Bend Toll	0.50
Lake Olympia Pkway	0.15
McHard Road FM 2234	0.30
Fort Bend Parkway Mainline	0.60
Fort Bend Parkway Extension	0.30
Westpark Toll	0.48
Westpark toll Grand Mission Mainline	0.30
Westpark HW6 westbound	0.21
Westpark Wilcrest Mainline	0.84
Westpark Gessner Road Entrance/Exit	0.21
Fondren East Exist	0.29
Fondren East Entrance	0.42
Fondren East Mainline	0.84
Fondren West Mainline	0.21

Source: H-GAC 2012

2.5.3 Transit Fares

Year 2009 transit fares were used as transit fare inputs to 2009 model validation. Table 2.6 presents the year 2009 transit fares, by service type, in 2009 dollars.

Table 2.6
Year 2009 Transit Fares
In 2009 Dollars

Local Bus	1.0
Light Rail	1.0
Express Bus	1.5
Commuter Bus	1.5
0-10 miles	1.5
11-15 miles	2.5
16-20 miles	3.0
>20 miles	3.5

2.5.4 Parking Costs

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

Table 2.7
Parking Costs for Activity Centers

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

Source: Houston METRO

3.0 Data Preparation and Transportation Network Development

Calibration and validation of the regional model was dependent upon observed travel behavior 1994 household, work place, commercial vehicle and external station travel surveys as well as a 2007 On-Board Transit Survey.

3.1 1994/1995 Travel Surveys

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

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

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

3.2 Estimation of Highway Supply Characteristics

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

The 2009 base year highway network includes key operational features for approximately 7,300 center-line miles of roadways in the Houston-Galveston TMA, and consists of nearly 17,000 roadway links (two-way, excluding centroid connectors). Each link’s physical and operating characteristics are described in a link data record. The Base Year 2009 network was constructed from the model calibration year 1995 network based on completed project information and input from local transportation agencies. Access to the highway network is provided by connecting links referred to as centroid connectors, which link internal TAZ centroids to nodes (points) in the highway network. These centroid connectors represent access to collectors, arterials, and other roadway facilities via local streets. The physical and operational characteristics represented with centroid connectors reflect zone size, proximity to the regional highway network, and the travel characteristics of local roadway facilities, which have the function of providing access to land uses within zones.

Data on physical attributes of the network, including roadway length, number of lanes, and median access type (divided or undivided) as well as operational characteristics such as average weekday traffic count and direction (one-way/two-way) were taken from the Roadway Inventory. Link data items such as facility type classification, 24-hour speed, and 24-hour capacity are derived either from the above information or from a vehicle trip assignment. Highway link facility types include nearly 40 different classifications. These are listed in Table 3.1 along with the link type codes for transit and HOV access.

3.2.1 Link Capacity

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

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

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

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

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

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

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

Table 3.2.1
Link Type Classification Codes

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

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

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

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

3.2.2 Link Speeds & Automobile Travel Times

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

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

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

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

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

3.2.3 Auto Network Centroid Connectors

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

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

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

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

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

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

<u>Area Type 2 - Urban</u>

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)

<u>Area Type 3 - Suburban</u>

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)

<u>Area Type 4 - Fringe Suburban</u>

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)

<u>Area Type 5 - Rural</u>

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

when link distance > 0.10 miles and <= 0.25 miles:
Travel Time (minutes) = (0.30 + 2.4 * (link distance - 0.1))
Travel Speed = 60 / (Travel Time / link distance)

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

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

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

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

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

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

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

Table 3.3
Centroid Connector Speeds

Area Type	Distance (miles)	Speed (mph)
CBD	.050	20.0
Urban	.95	40.0
Suburban	1.2	40.0
Fringe Suburban	1.7	40.0
Rural	1.8	40.0

Source: H-GAC

3.2.4 HOV Facilities

In 2009, barrier-separated HOV lanes existed in the following freeway corridors; these are:

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

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

- Katy Freeway
- Southwest Freeway

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

3.2.5 Toll Road Facilities

In the 2009 network, toll roads are coded comparably to any freeway link. The actual toll imposed on a vehicle is stored in a user-specified link field and accumulated into a separate toll matrix during the assignment process. Separate toll plaza links are included in the network specifically for this purpose. There are two freeways currently designated as toll roads; these are:

- Hardy Toll Road
- Sam Houston Tollway

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

3.2.6 Auto Modes

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

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

3.2.7 Additional Highway Characteristics

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

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

3.3 Estimation of Transit Supply Characteristics

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

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

3.3.1 Transit Routes and Coded Lines

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

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

3.3.2 Headway Calculation

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

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

Unlike base period service, which tends to be fairly evenly distributed over the entire period, peak service may vary substantially within the peak period. Express lines, for example, may provide relatively few bus trips over the entire period, but may concentrate these trips within a relatively small time interval. Assuming that these trips are appropriately targeted to the specific demand for peak period service, the perceived headway by riders (who will become familiar with the scheduling of the service) will be significantly better than the value implied by using a computation method identical to that for base period service. Therefore, peak headway calculations must be based upon the peak hour of service offered in the peak period, with an appropriate peak hour headway calculated.

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

3.3.3 Transit Travel Times

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

I. Simple assumed speed

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

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

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

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

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

3.3.4 Transit Path Building

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

The set of path building weights below was the final set of values used in the 2009 validated model (all times are in minutes):

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

3.3.5 Transit Modes

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

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

The auxiliary transit modes are:

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

4.0 Travel Forecasting Procedures

4.1 Introduction

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

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

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

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

4.2 Trip Generation

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

4.2.1 Trip Production

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

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

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

Table 4.1
Home-Based Work Person Trip Rates

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

Source: H-GAC

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

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

Source: H-GAC

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

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

Source: H-GAC

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

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

Source: H-GAC

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

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

Source: H-GAC

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

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

Source: H-GAC

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

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

Source: H-GAC

Table 4.8
Non-Home Based Other Person Trip Rates

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

Source: H-GAC

4.2.2 Trip Attraction

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

Table 4.9
Home-Based Work Person Trip Attraction Rates

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

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

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

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

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

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

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

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

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	Enroll A	Enroll B
1	0.5171	0.0000	0.3657	0.1483	1.2554	1.7793	0.744	0.4785
2	0.6037	0.0000	0.4646	0.1384	1.3048	1.8188	0.744	0.4785
3	0.8332	0.0000	0.7315	0.1384	1.4185	1.9869	0.744	0.4785
4	0.9651	0.0000	0.9885	0.1384	1.5322	2.1451	0.744	0.4785
5	1.0642	0.0000	1.1763	0.1384	1.6854	2.2933	0.744	0.4785

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

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0534	0.2922	1.0688	0.4258	0.3340	0.5928	0.6429	0.6847	0.4404
2	0.1013	0.2922	1.0521	0.4425	0.4342	0.6346	0.6429	0.6847	0.4404
3	0.1491	1.0020	0.7932	0.1002	0.5344	0.5845	0.6492	0.9936	0.6391
4	0.1478	1.1270	0.7431	0.0835	0.5511	0.5761	0.6555	1.0354	0.6659
5	0.1465	1.1690	0.3006	0.0751	0.496	0.4897	0.6555	1.0437	0.6713

Table 4.15
Non Home-Based Other Person Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.2123	1.4264	0.1783	0.1426	0.7608	0.7132	1.6998	1.4145	0.9098
2	0.2160	1.4959	0.2659	0.1219	0.7313	0.6538	1.6289	1.3740	0.8837
3	0.3343	2.8512	0.4424	0.1229	0.8111	0.7374	1.9295	1.5362	0.988
4	0.3344	3.6265	0.4533	0.1133	0.9570	0.7177	2.0399	1.5866	1.0204
5	0.3344	3.1442	0.3917	0.0783	0.8268	0.5483	1.7625	1.3708	0.8816

Table 4.16
Truck Vehicle Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.1081	0.2155	0.1648	0.2282	0.0887	0.0507	0.2789	0.1141	0.0734
2	0.1179	0.2155	0.1648	0.2409	0.0887	0.0380	0.3043	0.1141	0.0734
3	0.1646	0.2155	0.2789	0.2916	0.0887	0.0380	0.3043	0.1268	0.0815
4	0.1860	0.2282	0.3930	0.3550	0.0887	0.0254	0.3043	0.1268	0.0815
5	0.1860	0.2409	0.3930	0.4184	0.0887	0.0254	0.3043	0.1268	0.0815

Table 4.17
Taxi Vehicle Trip Attraction Rates

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

Table 4.18
External-Local Auto Vehicle Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.0139	0.0948	0.0692	0.0324	0.0614	0.0707	0.1333	0.1180	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	0.209	0.0607	0.0199	0.0682	0.0616	0.132	0.1227	0.0789

Table 4.19
External-Local Truck Vehicle Trip Attraction Rates

Area Type	Households	Retail	Office	Industrial	Govt.	Medical	ED-1	ED-2A	ED-2B
1	0.00732	0.0146	0.01116	0.01545	0.00601	0.00343	0.01889	0.00773	0.00497
2	0.00798	0.0146	0.01116	0.01631	0.00601	0.00258	0.02061	0.00773	0.00497
3	0.01114	0.0146	0.01889	0.01975	0.00601	0.00258	0.02061	0.00859	0.00552
4	0.01260	0.01545	0.02662	0.02404	0.00601	0.00172	0.02061	0.00859	0.00552
5	0.01260	0.01631	0.02662	0.02833	0.00601	0.00172	0.02061	0.00859	0.00552

4.2.3 Trip Generation Results

Table 4.20 summarizes the trip generation estimates by trip purpose.

Table 4.20
Regional Trip Estimates by Purpose

Purpose	2009 Trips	Proportion of Total
Home-Based Work Person Trips	3,097,514	17.0
Home-Based Non-Work Educational-1	2,144,192	11.8
Home-Based Non-Work Educational-School Bus	616,667	3.4
Home-Based Non-Work Retail	3,230,065	17.7
Home-Based Non-Work Airport	53,752	0.3
Home-Based Non-Work Other	2,917,352	16.0
Non-Home-Based Work-Based	1,908,548	10.5
Non-Home-Based Other	3,107,703	17.1
Truck	792,383	4.4
Taxi	41,355	0.2
External-Local Auto	252,041	1.4
External-Local Truck	43,814	0.2

Source: H-GAC Model Application Results

4.3 Trip Distribution

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

4.3.1 Person Trip Table Development

The Disaggregate Trip Distribution Model, or Atomistic Model, is used for trip distribution modeling in the Houston-Galveston TMA. This model is used to produce 13 trip tables for the HBW, HBNW-ED1, HBNW-ED1-BUS, HBNW-RETAIL, HBNW-OTHER, NHB-Work-Based, NHB-Other, Truck, Taxi, Extl-Auto, Extl-Truck purposes. A modified version of the Atomistic model is used to produce the various external-local vehicle trip tables. Attractions for the external-local trip purposes as well as the origins and destinations for the external-through purposes are based upon patterns derived from 1995 H-GAC External survey and grown to match year 2009 traffic volumes at the external stations. The underlying assumption in the Atomistic model is that trips occur between small parcels of land (atoms) rather than the defined zone structure; thus by dividing existing zones into atoms a more realistic interchange of intrazonal trips and short (less than five minutes) trips among adjacent zones is defined. In application, a gravity model analogy determines the number of trip interchanges between atoms and subsequently sums the trips to derive both intrazonal trips and zonal interchange volumes. The basic atomistic model formulation is:

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

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

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

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

The F-factors used in the 2009 validation were the same set that were developed as part of the 1995 calibration of the Track-1 model set. No changes to F-factors were made as part of the 2009 validation. The calibrated F-factors by purpose are shown in Tables 4.21 and 4.22.

K-factors historically, have been used to improve model performance in addressing two natural barriers within the Houston-Galveston TMA: the Houston Ship Channel and the separation between Galveston Island and the mainland. These physical barrier K-factors are included in the 1990 model for both work and non-work trip purposes.

Distinct socio-economic and land use characteristics that require introduction of K-factors are the under-representation of both HBW attractions to the Houston CBD and intra-county HBW trips for the surrounding seven counties. In addition to the CBD, three other major activity centers, (Greenway area, Galleria-Post Oak, and Texas Medical Center) also required K-factors. In the current model, the original 1995 model K-factors have been retained except in Brazoria County. Additional K-factors refinements were subsequently made for Brazoria County in conjunction with a county roadway planning effort.

Table 4.21
Calibrated F-Factors by Trip Purpose

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

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

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

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

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

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

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

Table 4.22
Calibrated F-Factors by Trip Purpose

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

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

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

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

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

Table 4.23
Average Modeled Trip Length by Purpose

Purpose	2009 Average Trip Length
Home-Based Work	21.49
HBNW to Education-1	8.61
HBNW to ED1-Bus	8.72
HBNW to Retail	10.72
HBNW to Airport	29.72
HBNW to Other	13.17
NHB Work-Based	13.02
NHB Other	11.08
Truck	18.78
Taxi	12.56
External-Local Auto	36.79
External-Local Truck	50.75

Source: H-GAC Model Application Results

4.4 Feedback Loops

Given that the trip-based model previously was structured to include non-iterative “feedback” to the mode choice components, the upstream components that were considered for the introduction of iterative feedback were the land use allocation model, trip generation model or the trip distribution (ATOM2) model. The current trip generation model does not include a measure of spatial separation in its structure, so that option was ruled out for implementation of an interim approach. The land use allocation model is structured to receive mode choice logsums and was a candidate. However, it was felt that modifications to the current land use allocation procedure would require procedural changes so encompassing as to make it infeasible as an interim approach. That left the trip distribution model as the remaining candidate for inclusion in an interim feedback technique. Therefore, it was decided that the trip distribution models would serve as the point at which measures of congested impedance are fed back from traffic assignment models.

Typically, although not exclusively, implementations of iterative feedback makes use of measures of spatial separation or attractiveness relative to congested conditions. In some implementations of iterative feedback to trip distribution, the trip distribution models are structured to separately distribute peak and off-peak trips so that representations of peak and off-peak impedances can be included in the feedback process. This method of feedback requires the development of peak and off-peak trip ends. There are also examples in which simplifying assumptions regarding the use of measures of congested and uncongested impedance have been made with respect to work and non-work trip distributions

These simplifying assumptions involve using measures of congested or peak conditions for work trip distribution and uncongested conditions for non-work purposes. These simplifying assumptions are used in the implementation of feedback in the H-GAC models. Congestion representing a 2-hour AM peak period are used to represent peak conditions for work trip distribution while impedances representing average daily congested impedance are used for non-work trip distribution.

4.4.1 Selection of Feedback Data

All feedback techniques make use of post-assignment travel times or speeds in some manner. Some techniques feedback these times directly, while other techniques use the times to update cost or logsum-based impedances that are used in the model component to which the data is being fed back. One of the motivations for feeding back logsum values based on assignment travel times is to account for variables in addition to travel time in the measurement of spatial separation or attractiveness of travel between areas. There is appeal in a technique that brings sensitivity beyond highway travel time to trip distribution. However, given the goal of implementation of an interim technique and potential difficulty in using log sums with the Atomistic gravity model used by H-GAC, another method used in practice to expand the measure of impedance was selected.

This method relies on the use of combined or composite impedance. This measure of impedance combines highway and transit travel time in such a manner as to reduce the travel time from that of the highway time through the inclusion of transit travel time. The method of measuring impedance was selected for implementation of feedback for the home-based work (HBW) trip purpose. The implementation of composite time was done in such a manner as to weight the contribution of transit travel time based on a measure related to likelihood of transit use. The weighting factor for transit travel time varies based on zonal household income as shown below:

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

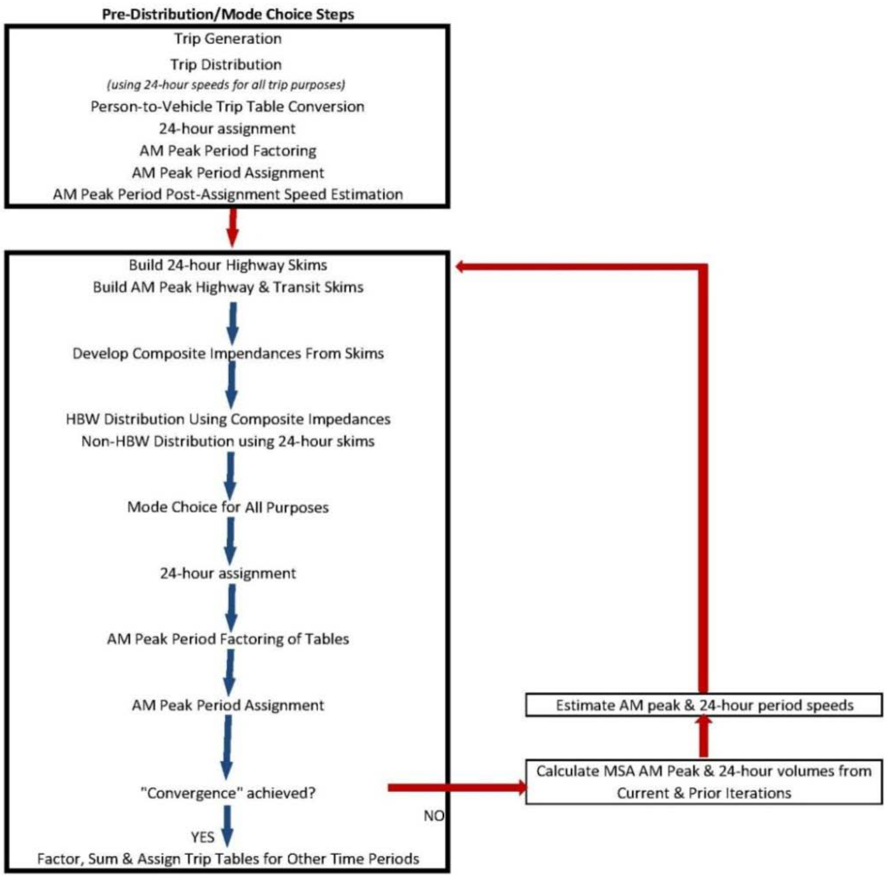
An example application of the composite time formulation with example travel times is presented in Table 4.24. The weighting factors used in the feedback procedure represent the regional mode shares for each of the 5 HBW trip purposes.

Table 4.24
Composite Time 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%

Travel times used to measure highway impedance are estimated based upon post-processed speeds from a 2-hour AM peak period assignment. The transit travel time component is based on peak transit service levels. Given that transit shares are relatively low for non-work trips relative to work trips, the use of composite impedance was limited to work trips only. The feedback technique implemented for the non-work purposes uses highway travel times directly from a 24-hour highway traffic assignment. Figure 4.1 presents a diagram of the model application process with inclusion of the feedback component.

Figure 4.1
Interim Feedback Procedure



The use of a technique that includes variation of measured impedance by income necessitated a change to the home-based work trip generation model. The trip generation model was modified and re-calibrated to produce HBW trip productions and attractions by income group. Additionally, the HBW trip distribution process was modified to create HBW trip tables for each of the five income groups.

Both the HBW and non-work feedback use 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 are 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 24-hour assignment link volumes are calculated and input to the BPR-based assignment function to calculate average daily travel times.

4.4.2 Measurement of Convergence

A variety of methods of measuring convergence or equilibrium are in practice. These range from running a fixed (i.e., predetermined – never varying) number of iterations to methods that measure changes in link –based and/or matrix-based values. Most approaches seem to focus on two criteria; changes in trip table flow and changes in some measure of link flow such as volume, speed or travel time. H-GAC's feedback procedure relies on several forms of measurement of equilibrium or stability and more than one procedure for quantifying change between iterations.

Root mean square change (RMSC) and a statistic named total misplaced flow (TMF) are methods suggested in the literature and discussion among practioners as appropriate for measuring stability of matrix-based values. TMF measure the sum of the absolute values of cell differences divided by the sum of all cell values. Many different measures of stability were tested and evaluated as part of the implementation of feedback.

Both RMSC and TMF were evaluated to measure stability of two types of matrix-based values in the interim feedback procedure; trip demand tables and zonal impedance (skim) tables. The trip table-based measures of stability are based on post-mode choice modal trip tables; the drive alone and total shared ride highway trip tables for the HBW trip purpose and the combined HBNW trip purposes.   Zonal impedance matrices were measured for stability using RMSC of AM peak and 24-hour zonal impedance tables. As the HBW trip purpose is segmented by income to facilitate the use of composite impedance, one of five possible measures of AM peak composite impedance were selected for stability measurement. Highway travel time is the basis for the 24-hour zonal impedance measure. Although matrix-based measures are accepted measures employed in feedback, published discussion of feedback implementations suggests that some differences among values of each iteration may not be revealed if viewed strictly at the matrix level. Therefore, H-GAC has also evaluated several link-based measures of stability in the interim feedback procedure.

Link-based measures of changes in attributes among iterations can provide a tighter measure of convergence than matrix-based measures. One statistic cited in practioner discussions is 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:

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

Evaluation of stability measures made use of the GEH statistic for assigned volumes from both an AM peak period and 24-hour assignment as these volumes are both utilized in the feedback procedures – AM peak period for feedback to HBW and 24-hour volumes for the non-work purposes.

In addition to the volume-based GEH statistic, the stability measure evaluation included measures of changes in link travel times to determine stability. As two sets of travel times are used in feedback, the stability measures also involve two sets of travel times. The percent RMSC of both AM peak and 24-hour link travel times were evaluated to determine stability. A second link-based volume change measure was evaluated as part of the feedback implementation. The criterion for this measure is the percent of links for which the change in link assigned 24-hour volume between iterations is greater than five percent.

4.4.3 Re-calibration of distribution f-factors

As the measure of spatial separation was changed from a look-up table-based 24-hour average speed to be AM peak composite impedance for the HBW trip purpose and 24-hour assignment based highway travel time, trip distribution f-factors were re-calibrated. The modifications to the trip distribution process required the calibration of f-factors for each of the income segmentations of HBW trips. Table 4.25 presents the desired and model resulting mean trip length for each of the five HBW trip purposes. The re-calibrated base year f-factors are presented in detail in Appendix A.

Table 4.25
Hbw Trip Length Results

Market Segment	Mean Trip Length (Network Minutes)	
	Survey-Based	Model Results
Income Group 1	20.21	20.19
Income Group 2	22.50	22.48
Income Group 3	22.97	22.85
Income Group 4	26.83	26.81
Income Group 5	25.76	25.74

As with the HBW trip distributions, base year f-factors were re-calibrated for the non-work trip purposes. Table 4.26 presents the survey observed and model resulting mean trip length. Appendix A contains the listing of resulting f-factors.

Table 4.26
Non-Work Purpose Trip Length Results

Trip Purpose	Mean Trip Length (Network Minutes)	
	Survey-Based	Model Results
HBNW-Education	9.01	8.95
HBNW-Retail	10.96	11.25
HBNW-Other	13.16	13.27
HBNW-Airport	22.64	24.38
NHB Work-Based	13.18	13.42
NHB Non-work	11.03	11.11
TRUCK	18.91	19.34
TAXI	12.99	12.95

4.4.4 Convergence/Stability Measure Results

Tables 4.27 & 4.28 present the convergence or stability measures results from the implementation of the feedback procedures for the base year.

TABLE 4.27
Feedback Convergence – HBW

Iteration	%Links Over 5% Volume Change AM Peak Period	% RMSC AM Peak Period Link Travel Time From Assign	% RMSC AM Peak Period Link Travel Time From Speed Model	% Links Over 5% AM Peak Period GEH	% RMSC HBW DA Trip Table	% RMSC HBW Share Ride Trip Table	% TMF HBW DA Trip Table	% TMF HBW Share Ride Trip Table	% RMSC HBW INC GRP 1 SKIM	% TMF HBW INC GRP 1 SKIM
1	--	--	--	--	--	--	--	--	--	--
2	22.55%	1.05%	1.30%	5.89%	0.02%	0.02%	7.20%	9.55%	6.90%	3.12%
3	6.23%	0.78%	0.96%	1.54%	0.00%	0.00%	2.80%	4.67%	0.73%	0.99%
4	4.45%	0.67%	0.67%	0.56%	0.00%	0.00%	2.01%	3.78%	0.16%	0.47%
5	3.50%	0.59%	0.66%	0.54%	0.00%	0.00%	1.85%	3.58%	0.08%	0.33%
6	4.43%	0.81%	0.81%	0.77%	0.00%	0.00%	1.78%	3.49%	0.05%	0.26%
7	4.92%	0.78%	0.84%	0.91%	0.00%	0.00%	1.72%	3.41%	0.03%	0.20%
8	3.49%	0.38%	0.59%	0.52%	0.00%	0.00%	1.68%	3.36%	0.02%	0.17%

TABLE 4.28
Feedback Convergence – HBNW

Interation	%Links Over 5% Volume Change 24-hour Assign	% RMSC 24-hour Link Travel Time From Assign	% Links Over 5% 24-hour GEH	% RMSC HBNW DA Trip Table	% RMSC BNW Share Rid Trip Table	% TMF HBNW DA Trip Table	% TMF NW Share R Trip Table	% RMSC Daily 3+ Person Pay SKIM	% TMF Daily 3+ Person Pay SKIM
1	--	--	--	--	--	--	--	--	--
2	19.83%	2.25%	17.16%	0.02%	0.02%	5.39%	5.05%	5.57%	2.15%
3	5.70%	0.90%	3.81%	0.01%	0.01%	1.52%	1.60%	0.51%	0.86%
4	6.70%	0.86%	4.53%	0.00%	0.00%	0.75%	0.79%	0.14%	0.44%
5	4.45%	0.67%	2.81%	0.00%	0.00%	0.53%	0.57%	0.06%	0.29%
6	4.98%	0.64%	2.88%	0.00%	0.00%	0.47%	0.51%	0.03%	0.21%
7	4.20%	0.57%	2.22%	0.00%	0.00%	0.44%	0.47%	0.02%	0.17%
8	3.04%	0.51%	1.71%	0.00%	0.00%	0.43%	0.46%	0.02%	0.15%

The data indicated that almost universally, these statistics achieve stability after four to five iterations. In order to streamline the application of feedback in the model set, a subset of the measures listed in Tables 4.27 and 4.28 were identified for use in model application. Along with the selected measures, the numeric values of the measures that were deemed to represent "stability" were determined. Table 4.29 presents the set of selected measures and associated values of stability.

Table 4.29
Stability Measures Selected For Application
&
Associate "Stability" Values

Measure	Value of "Stability"
% Links Over 5% Change in 24-hour volume	5.00%
% Links Over 5% GEH – 24-hour volume	3.00%
% TMF – HBW Drive-Alone Trip Table	2.00%
% TMF – HBNW Drive-Alone Trip Table	1.00%
%RMSC – HBW Income Group 1 Composite Skim	0.10%
% RMSC 24-hour 3+ Person Pay Skim	0.10%

As a result of this finding and a practical need to keep model run times from becoming a hindrance to efficient use of the models, one additional control on feedback, in addition to the statistical measures cited above is the number of iterations. The maximum number of iterations has been set to 6 iterations.

4.4.5 Validation

While evaluations of the modeled trip lengths against observed and prior modeled trip lengths and convergence statistics are useful and important aspects of the validation of the feedback procedures, it was equally important to evaluate the feedback procedure performance in terms of the ultimate model output – travel demand in terms of vehicle miles of travel (VMT).

The modified models were applied to and comparisons made to base year VMT as estimated by the models without feedback. In terms of comparisons to modeled VMT, the goal of the validation is for VMT with feedback to be essentially unchanged from VMT without feedback as the VMT without feedback represents "validated" VMT for the base year. Table 4.30 presents comparisons of 1995 modeled VMT at the county level and for the region in total.

Table 4.30
Modeled 24-Hour VMT By County

County	No Feedback	Feedback
Brazoria	4,047,006	4,222,496
Chambers	2,073,274	2,089,269
Fort Bend	5,146,546	5,162,100
Galveston	3,983,497	4,132,596
Harris	73,563,440	71,771,672
Liberty	1,716,382	1,763,700
Montgomery	6,172,912	6,069,545
Waller	1,332,776	1,327,930
Total VMT	98,035,833	96,539,308

VMT in Harris County and Montgomery County with feedback is 1%-2% lower while VMT in the other counties is virtually the same or higher. This reflects that the congestion levels (AM peak period and 24-hour) in Harris County and to a lesser extent, Montgomery County are such they result in lower average trip lengths in terms of distance

Table 4.31 presents VMT comparison of model applications by facility type.

Table 4.31
Modeled 24-Hour VMT
By Facility Type

Facility Type	No Feedback	Feedback
Freeways	41,210,627	40,290,983
Tollways	2,161,675	2,208,904
Principal Arterials	15,851,136	15,684,171
Other Arterials	24,758,734	24,444,668
Collectors	6,784,006	6,807,773
Frontage Roads & Ramps	7,269,655	7,102,810
Total VMT	98,035,833	96,539,308

The VMT decrease, although small, is somewhat higher for freeway facilities that non-freeway facilities. This likely reflects the shorter average trip distances in terms of length resulting from the implementation of feedback. The slight increase in VMT on tollways is possible due minor re-orientation of travel of HBW trips along tollway corridors of the highway system in response the use of AM peak period impedance in the distribution of HBW trips.

4.5 Mode Choice

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

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

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

- Transit-drive access Kiss-and-Ride

Mode usage is calculated for five income levels and three individual trip purposes (Home-Based Work, Home-Based Non-Work, and Non-Home Based). The model was originally estimated based upon 1995 Home-Interview and On-Board Transit Rider Survey data and was calibrated through the mathematical adjustment of bias constants[1] to replicate locally observed travel values. The model has been validated against 2007 On-Board survey data.

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

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

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

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

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

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

The second modification was to add an additional household size variable to the model. In this way, the model would be sensitive to the size of a household in determining the probability of a multi-occupant trip. In the case of a 2-person household, the probability for a 3 or more occupant home-based non-work or non-home-based trip is much lower that for a 3 or more person household given that many of these trips are made by members of the same household.

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

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

The complete set of coefficient values for the Home-Based Work nested logit model is shown in Table 4.32. The Home-Based Non-Work and Non-Home Based values are presented in Tables 4.33 and 4.34 respectively.

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

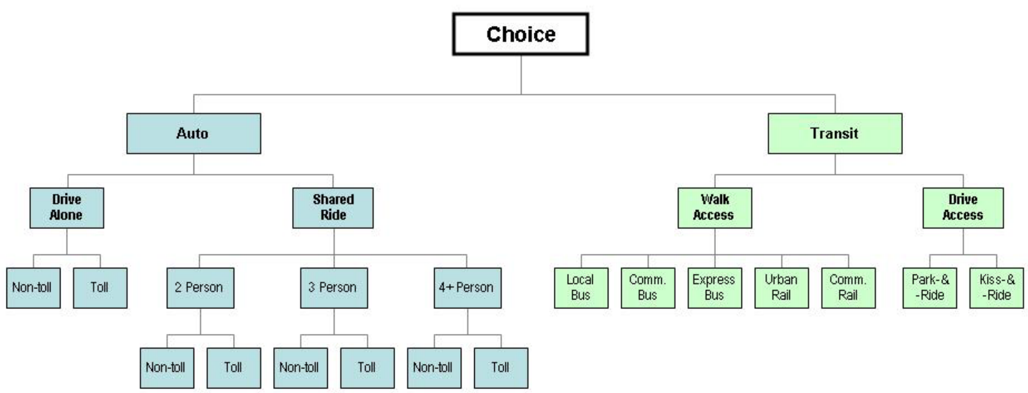

Table 4.32
Coefficient Values for Home-Based Work Mode Choice Model

Variable	Multinomial Value	Mode
In-vehicle time	-0.02203	All modes
1 Wait less than 4.5 minutes	-0.05680	Transit
1 Wait over 4.5 minutes	-0.02203	Transit
Walk	-0.05680	Transit
Transfer time	-0.05680	Transit
Number of transfers	-0.08810	Transit
Transit fare (all)	-0.00614	Transit
Drive to transit time	-0.05680	Transit

Parking cost (all)	-0.01540	Highway
Highway Operating Cost (all)	-0.00614	Highway
Tolls (income group)	-0.00819 -0.00717 -0.00614 -0.00512 -0.00410	Highway
HOV/Toll Time Savings	+0.01542	Highway
Residential Density Indicator	+0.13947	Transit (Walk)
Nesting Coefficients		
Between transit and access	0.75000	Transit
Between access and path	0.60000	Transit
Between single and drive group	0.75000	Highway
Between group and 2/4+	0.60000	Highway
Between 2/4+ and toll/free	0.45000	Highway
Between drive and toll/free	0.45000	Highway

Table 4.33
Coefficient Values for Home-Based Non-Work Mode Choice Model

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

Table 4.34
Coefficient Values for Non-Home Based Mode Choice Model

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

4.4.4 Calibration of Modal Bias Constants

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

It is essential that the mode choice model set be able to estimate observed modal trips within a reasonable degree of accuracy. The models were applied at the aggregate (zone) level and the mode specific constants were adjusted to match observed 1995 control values. Applying the models at the aggregate level utilizes the full set of network based travel times and costs, zonal level socio-economic and other related data (i.e., parking costs) and the input trip distribution model person trip tables. In this manner, the models are applied as they would be in forecasting future year trips. Tables 4.35 - 4.37 summarize the final set of bias constant values for each trip purpose.

Table 4.35
Modal Bias Constants - Home Based Work Mode Choice Model

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

Table 4.36
Modal Bias Constants - Home Based Non Work Mode Choice Model

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

Table 4.37
Modal Bias Constants - Non Home Based Mode Choice Model

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

4.5 Commercial Vehicles

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

4.6 External Travel

External trips are categorized into two general categories: external local (external-internal travel) and external through (external-external travel). Within these categories, truck and auto trips have been separated, resulting in four different trip purposes: external-local auto, external-local truck, external-through auto and external-through truck. External-local auto and truck productions are estimated based on the year 2009 counted volume at the external station and the shares of external-local auto and truck as estimated from the H-GAC 1995 External-station survey. External-local attractions are estimated based upon the household survey. External-local attractions are scaled to match external-local productions.

The trip distribution model employs the gravity model form in conjunction with a specified trip length frequency curve. External through trip matrices are derived by frataring the 1995 External Survey based external-through trip tables to match estimated year 2009 external-through trip ends. The year 2009 estimated external through trip ends are based upon the external-through trip share as estimated at each station based upon the 1995 External Survey.

4.7 Trip Assignment

4.7.1 Highway Trip Assignment Methodology

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

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

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

The constraint is applied to limit the magnitude of the impedance adjustment, the maximum of which varies by iteration. After the initial assignment, the maximum impedance factor is two (essentially reducing the 24-hour speed by one-half) and is increased by one for each of the subsequent iterations. The final assignment results are computed following the six iterations, using a weighted average of the link volumes from those iterations. The iteration weights specified for the 2009 base year assignment are determined by an equilibrium capacity restraint process, where each trip is assigned the path with the shortest travel time until equilibrium is achieved.

4.7.2 Comparison to 2009 Counted Volumes

In the 2009 network, there are 3,096 highway links (one-way links) excluding centroid connectors. Of the 3,096, there are 321 with count based volume estimates. To demonstrate the validity of the models, comparison of the assigned versus counted 2009 TxDOT District VMT is normally summarized to demonstrate the capabilities of the models in matching estimated 2009 base year conditions

Table 4.38 summarizes the total assigned VMT on all 27,714 links by 5 roadway types. The assigned VMT on the links with counted volumes are also summarized by roadway type. The assigned VMT as a percentage of the counted VMT was computed and is summarized for each of the roadway types. As may be observed, the assigned VMT on all roadway types are within 106.71% of the counted VMT estimates.

Table 4.39 summarizes the total assigned VMT on all 27,714 links by 5 area types. The assigned VMT on links with counted volumes are also summarized by area type. The assigned VMT as a percentage of the counted VMT was computed and is summarized for each of the area types. While the CBD Assigned VMT is approximately 115.33% of counted VMT, this is not unusual for CBD's and is considered within acceptable limits. The assigned and counted VMT in the other area types compare very favorably.

Table 4.40 summarizes the total assigned VMT on all 27,714 links by the 8 counties in the region. The assigned VMT on the links with counted volumes are also summarized by county. The assigned VMT as a percentage of the counted VMT was computed and is summarized for each of the counties. The assigned VMT in seven of the eight counties are within 108% of the counted VMT wich is considered acceptable for a macro regional model. However, Mongonmery County's VMT is under eforceaste by roughly 3% of the counted which was considered acceptable.

Overall the comparisons of the assigned and counted VMT were considered acceptable and reasonably demonstrate that the models reasonably replicates the observed conditions for 2009.

Table 4.38
2009 VMT by Roadway Type

Roadway Type	Number of links	Total Assigned VMT (all links)	Number of Links With Counts	Counted VMT on Links With Counts	Assigned VMT on Links With Counts	Assined VMT as Percent of Counted VMT
Freeway	3,096	57,338,930	321	17,085,813	18,103,319	105.96%
Toll Roads	370	8,974,332	181	2,891,982	3,063,313	105.92%
Prin. Arterial	15,877	21,869,354	1,516	9,249,211	10,171,989	109.98%
Other Arterial	3,090	35,826,184	491	8,511,141	8,988,893	105.61%
Collectors	5,281	13,303,598	460	2,120,841	2,206,012	104.02%
All Types	27,714	137,312,398	2,969	39,858,988	42,533,526	106.71%

Table 4.39
2009 VMT by Area Type

Roadway Type	Number of links	Total Assigned VMT (all links)	Number of Links With Counts	Counted VMT on Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
CBD	759	688,915	63	155,008	178,778	115.33%
Urban	5,046	22,449,298	247	4,625,864	4,668,608	100.92%
Urban Fringe	10,983	62,331,913	852	13,754,450	15,077,802	109.62%
Suburban	6,928	34,089,653	819	10,702,778	11,928,114	111.45%
Rural	3,998	17,752,619	988	10,620,888	10,680,224	100.56%
All Types	27,714	137,312,398	2,969	39,858,988	42,533,526	106.71%

Table 4.40
2009 VMT by County

County	Number of links	Total Assigned VMT (all links)	Number of Links With Counts	Counted VMT on Links With Counts	Assigned VMT on Links With Counts	Assigned VMT as Percent of Counted VMT
Brazoria	2,069	6,157,728	352	3,358,720	3,633,381	108.18%
Chambers	487	2,608,644	143	1,689,104	1,794,084	106.22%
Fort Bend	1,934	9,437,550	350	3,985,598	4,220,268	105.89%
Galveston	1,911	5,376,550	417	2,706,413	2,910,124	107.53%
Harris	19,596	99,880,118	1,053	21,270,706	23,119,048	108.69%
Liberty	588	2,212,197	199	1,821,769	1,891,279	103.82%
Montgomery	1,653	9,612,373	315	3,837,893	3,719,221	96.91%
Waller	476	2,027,238	140	1,188,785	1,246,121	104.82%
All Counties	27,714	137,312,398	2,969	39,858,988	42,533,526	106.71%

5.0 HPMS VMT ADJUSTMENT

5.1 INTRODUCTION

H-GAC has validated its travel models to the year 2009. As part of the validation, there is a need to re-calculate the factor by which travel model VMT is made to be consistent with VMT estimated by the FHWA Highway Performance Monitoring System (HPMS). The H-GAC Regional Travel Models have been validated to observed vehicle miles of travel (VMT) that are estimated based on roughly 14,000 traffic counts. The estimates and forecasts of vehicle miles of travel produced by the model set are used directly in all transportation planning applications conducted by H-GAC and its transportation planning partners. For purposes of air quality conformity analysis of RTPs and TIPs and the development of State Implementations Plans, H-GAC, through consultation with the Texas Department of Transportation (TxDOT), Texas Commission on Environmental Quality (TCEQ), U.S. DOT and EPA has chosen to reconcile its Base Year (2009) model estimated regional VMT against regional 2009 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 2009 estimated regional VMT to HPMS estimated 2009 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.

HPMS estimated average non-summer weekday travel (ANSWT)
= (HPMS AADT) * (AADT to Non-Summer Weekday Travel Adjustment Factor[A])
= (137,109,395) * (1.066)
= 146,158,615

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

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)
= (146,158,615) / (153,213,192)
= .95396

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
CALIBRATED F-FACTORS

Separation	HBW F-FACTORS				
	Income Group 1	Income Group 2	Income Group 3	Income Group 4	Income Group 5
1	193.5399480	224.805817	227.168518	257.133606	225.118500
2	145.8673860	156.406219	155.734741	173.117340	177.418030
3	121.2046890	122.988182	122.475319	131.121277	144.024353
4	107.0372310	111.263832	111.745796	115.372940	110.914803
5	100.0000000	100.000000	100.000008	100.000000	100.000000
6	91.1710660	90.104332	88.956001	85.868401	85.437187
7	82.1610570	80.702675	79.376579	74.317177	73.472763
8	73.5569310	71.652832	69.968178	64.030975	62.958603
9	66.1929320	64.557655	62.790874	57.176315	55.906662
10	58.7815590	57.275101	55.724564	50.441746	48.769520
11	52.3332290	51.473293	49.886131	44.943501	43.466530
12	46.4198270	46.228230	44.844692	40.358067	39.176022
13	40.9369350	41.468971	40.391605	36.387459	35.156750
14	36.1901700	36.879593	36.280449	32.595196	31.825615
15	32.0972330	32.930862	32.642078	29.555077	29.064293
16	28.4350470	29.641336	29.496498	27.168694	26.854813
17	25.2358930	26.791239	26.748756	24.983006	25.097897
18	22.4058720	24.170610	24.272346	22.918192	22.877329
19	19.8913190	21.858486	22.006355	21.048073	21.290363
20	17.8734000	19.929327	20.087097	19.482216	19.947424
21	16.1059930	18.213942	18.374798	17.965721	18.279957
22	14.4734020	16.709070	16.889065	16.710806	16.927351
23	13.0301260	15.271107	15.448472	15.487744	15.735168
24	11.7612390	14.021821	14.116104	14.358464	14.509348
25	10.7696050	13.050478	13.011118	13.399844	13.431287
26	9.7618610	12.047392	11.953997	12.335619	12.177731
27	8.9252370	11.252378	11.051552	11.502245	11.214786
28	8.1783630	10.527154	10.325975	10.896264	10.341002
29	7.4243570	9.728634	9.504676	10.103153	9.373228
30	6.7879670	9.039663	8.739743	9.351624	8.516640
31	6.1733400	8.390810	8.067534	8.670732	7.690273
32	5.5947590	7.753361	7.444358	8.051167	6.992890
33	5.0882440	7.151279	6.863648	7.471849	6.351751
34	4.6263800	6.613328	6.333907	6.954888	5.779418
35	4.2053090	6.126048	5.872572	6.539565	5.315190
36	3.8066960	5.667048	5.429954	6.182436	4.937048
37	3.4466300	5.256234	4.998549	5.806795	4.571177
38	3.1134870	4.834994	4.583277	5.439839	4.214360
39	2.8186760	4.465202	4.173503	5.035622	3.878964
40	2.5434670	4.121138	3.844949	4.780489	3.650200
41	2.2779720	3.788419	3.557359	4.571378	3.404158
42	2.0351190	3.478450	3.267293	4.295650	3.172407
43	1.8176770	3.185252	2.993864	4.042605	2.945335

Separation	HBW F-FACTORS (cont.)				
	Income Group 1	Income Group 2	Income Group 3	Income Group 4	Income Group 5
44	1.6294390	2.906356	2.744852	3.844606	2.741962
45	1.4660550	2.647066	2.514011	3.659094	2.594773
46	1.3197060	2.412398	2.310199	3.474955	2.445430
47	1.1709800	2.198966	2.125073	3.275410	2.292953
48	1.0397740	2.028260	1.951995	3.099101	2.166251
49	0.9270130	1.878897	1.788786	2.959670	2.035977
50	0.8279340	1.729236	1.647894	2.836301	1.908877
51	0.7351360	1.565926	1.511910	2.700750	1.797018
52	0.6441970	1.401761	1.371092	2.551227	1.693516
53	0.5587310	1.249565	1.246254	2.431489	1.612538
54	0.4858880	1.121262	1.136127	2.322512	1.535649
55	0.4312270	1.020676	1.031737	2.204895	1.463647
56	0.3825930	0.926789	0.949398	2.111654	1.395852
57	0.3383210	0.836800	0.873295	2.011028	1.333808
58	0.2977710	0.755757	0.799402	1.904434	1.273309
59	0.2614680	0.695053	0.737366	1.811588	1.211228
60	0.2295100	0.639070	0.684614	1.740588	1.143764
61	0.2003990	0.585458	0.637018	1.683035	1.091593
62	0.1755010	0.536867	0.591281	1.619308	1.053417
63	0.1532990	0.483669	0.548060	1.563874	1.018665
64	0.1346210	0.436894	0.505605	1.502935	0.974233
65	0.1218540	0.401879	0.468018	1.444618	0.933911
66	0.1104410	0.367349	0.438308	1.392656	0.904356
67	0.0972090	0.341744	0.414402	1.348912	0.869003
68	0.0838600	0.318097	0.386171	1.309075	0.826306
69	0.0710680	0.293480	0.351635	1.265403	0.776923
70	0.0618840	0.270888	0.317280	1.210868	0.732311
71	0.0573490	0.247172	0.288755	1.146894	0.699041
72	0.0508340	0.223008	0.269214	1.080420	0.656676
73	0.0442000	0.207292	0.256171	1.033580	0.613994
74	0.0390670	0.194424	0.242287	1.020314	0.586383
75	0.0361110	0.184743	0.223421	1.007474	0.560884
76	0.0342540	0.174864	0.203564	0.982002	0.535217
77	0.0315180	0.159889	0.190538	0.951620	0.507819
78	0.0279140	0.145601	0.188235	0.919550	0.483009
79	0.0226970	0.135178	0.184035	0.905968	0.459681
80	0.0188640	0.124350	0.170690	0.895888	0.433366
81	0.0164270	0.115361	0.151553	0.868800	0.411025
82	0.0146460	0.108489	0.136973	0.833719	0.393217
83	0.0134610	0.101833	0.129429	0.784455	0.373697
84	0.0128590	0.096453	0.126233	0.748552	0.355833
85	0.0110310	0.088481	0.125584	0.724311	0.340907
86	0.0093120	0.079183	0.122065	0.694451	0.320112

Separation	HBW F-FACTORS (cont.)				
	Income Group 1	Income Group 2	Income Group 3	Income Group 4	Income Group 5
87	0.0078110	0.071712	0.115014	0.659309	0.295841
88	0.0065240	0.065817	0.109062	0.615217	0.275271
89	0.0055740	0.062266	0.107200	0.568132	0.253264
90	0.0048950	0.060476	0.101840	0.531712	0.234567
91	0.0042940	0.057104	0.096748	0.512936	0.220552
92	0.0037770	0.051838	0.091911	0.492752	0.205135
93	0.0033270	0.047649	0.083396	0.460575	0.191069
94	0.0029830	0.044912	0.075439	0.431171	0.178501
95	0.0026460	0.040649	0.070385	0.407284	0.161426
96	0.0024050	0.038617	0.065669	0.384152	0.145487
97	0.0022030	0.036686	0.061269	0.361870	0.132345
98	0.0020420	0.034851	0.057164	0.333827	0.117717
99	0.0019210	0.033109	0.053334	0.313804	0.105550
100	0.0018410	0.030474	0.049761	0.287870	0.094108
101	0.0017710	0.026038	0.046427	0.267449	0.089873
102	0.0016460	0.022480	0.043316	0.249999	0.085829
103	0.0016150	0.019607	0.040414	0.233031	0.081967
104	0.0015745	0.016989	0.037706	0.217549	0.078278
105	0.0015340	0.014798	0.031856	0.209489	0.074756
106	0.0014630	0.012885	0.027806	0.202917	0.071392
107	0.0014070	0.011161	0.023942	0.188927	0.068179
108	0.0013578	0.009959	0.021251	0.178976	0.065111
109	0.0013102	0.009087	0.018690	0.169536	0.062181
110	0.0012644	0.008048	0.016446	0.161401	0.059383
111	0.0012201	0.007220	0.014487	0.152409	0.056711
112	0.0011774	0.006537	0.012960	0.144674	0.051945
113	0.0011362	0.005853	0.011643	0.136872	0.050924
114	0.0010964	0.005297	0.010628	0.128902	0.048372
115	0.0010581	0.005060	0.009557	0.120862	0.045645
116	0.0010210	0.004761	0.008815	0.112805	0.042551
117	0.0009853	0.004462	0.007520	0.105867	0.039087
118	0.0009508	0.004019	0.006694	0.099436	0.035281
119	0.0009170	0.003637	0.006025	0.092476	0.032459
120	0.0008620	0.003491	0.005422	0.086002	0.029862
121	0.0008510	0.003360	0.004880	0.079982	0.027473
122	0.0008400	0.003108	0.004392	0.074383	0.025275
123	0.0007980	0.002797	0.003953	0.069177	0.023253
124	0.0007581	0.002518	0.003558	0.064334	0.021393
125	0.0007202	0.002266	0.003202	0.059831	0.019681
126	0.0006662	0.001899	0.002882	0.055643	0.018107
127	0.0006162	0.001709	0.002593	0.051748	0.016658
128	0.0005546	0.001538	0.002334	0.048125	0.015326
129	0.0004991	0.001384	0.002101	0.044757	0.014100

Separation	HBW F-FACTORS (cont.)				
	Income Group 1	Income Group 2	Income Group 3	Income Group 4	Income Group 5
130	0.0004492	0.001246	0.001891	0.041624	0.012972
131	0.0004043	0.001121	0.001702	0.038710	0.011934
132	0.0003639	0.001009	0.001531	0.036000	0.010979
133	0.0003275	0.000908	0.001378	0.033480	0.010101
134	0.0002947	0.000818	0.001240	0.031137	0.009293
135	0.0002653	0.000736	0.001116	0.028957	0.008549
136	0.0002387	0.000662	0.001005	0.026930	0.007865
137	0.0002149	0.000596	0.000904	0.025045	0.007236
138	0.0001934	0.000536	0.000814	0.023292	0.006657
139	0.0001740	0.000483	0.000733	0.021661	0.006125
140	0.0001566	0.000434	0.000659	0.020145	0.005635
141	0.0001410	0.000391	0.000593	0.018735	0.005184
142	0.0001269	0.000352	0.000534	0.017424	0.004769
143	0.0001142	0.000317	0.000481	0.016204	0.004388
144	0.0001028	0.000285	0.000433	0.015070	0.004037
145	0.0000925	0.000257	0.000389	0.014015	0.003714
146	0.0000832	0.000231	0.000350	0.013034	0.003417
147	0.0000749	0.000208	0.000315	0.012121	0.003143
148	0.0000674	0.000187	0.000284	0.011273	0.002892
149	0.0000607	0.000168	0.000255	0.010484	0.002661
150	0.0000546	0.000152	0.000230	0.009750	0.002448

Separation	Non-Work Trip Purpose F-Factors							
	HBNW-ED1	HBNW-Retail	HBNW-Other	HBNW-Airport	NHB-Work	NHB-Other	Truck	Taxi
1	256.45900	346.87640	304.95210	150.59800	257.13361	225.11850	358.87470	325.15990
2	198.48100	249.07710	230.83640	135.68370	173.11734	177.41803	255.09550	266.01260
3	161.50010	184.89890	181.52440	127.50500	131.12128	144.02435	188.56410	194.56840
4	133.48090	137.51970	134.26450	120.35260	115.37294	110.91480	137.05000	137.66310
5	100.00000	100.00000	100.00000	110.92550	100.00000	100.00000	100.00000	100.00000
6	78.18950	73.77780	76.83010	100.00000	85.86840	85.43719	76.36750	74.79610
7	62.16490	54.88590	59.79740	88.73240	74.31718	73.47276	60.39510	56.89370
8	48.69890	42.26370	46.85840	79.77370	64.03098	62.95860	48.19320	43.43170
9	38.37570	33.49440	38.36650	72.94130	57.17632	55.90666	39.27750	33.71210
10	30.39110	25.73650	30.70200	67.43940	50.44175	48.76952	33.26020	26.97680
11	24.20230	20.50730	25.00420	61.18500	44.94350	43.46653	28.19690	22.09960
12	19.56380	16.25200	20.92380	54.92430	40.35807	39.17602	24.04960	18.08280
13	15.63390	12.82560	17.01290	48.70500	36.38746	35.15675	20.56340	15.24760
14	12.90490	10.48910	14.49360	43.30080	32.59520	31.82562	18.09550	13.00140
15	10.49280	8.27400	11.94530	38.54760	29.55508	29.06429	16.04120	11.01440
16	8.53480	6.68100	10.25860	34.43980	27.16869	26.85481	14.08330	9.27160
17	7.06510	5.56290	8.68070	30.80040	24.98301	25.09790	12.64430	7.96930
18	5.76190	4.47310	7.38110	27.03290	22.91819	22.87733	11.17850	6.64110
19	4.70910	3.61800	6.35100	23.24510	21.04807	21.29036	10.13180	5.81340
20	3.84680	3.03300	5.37920	20.64490	19.48222	19.94742	9.12230	5.03340
21	3.25260	2.50860	4.78690	18.54900	17.96572	18.27996	8.42240	4.30580
22	2.68580	2.07170	4.12130	16.58050	16.71081	16.92735	7.73750	3.83400
23	2.27320	1.72950	3.66970	14.66440	15.48774	15.73517	7.19200	3.42680
24	1.87330	1.45400	3.23640	13.00470	14.35846	14.50935	6.61110	2.96450
25	1.46090	1.21710	2.81600	11.55340	13.39984	13.43129	6.12140	2.75190
26	1.18140	1.02070	2.56470	10.33720	12.33562	12.17773	5.62670	2.36820
27	0.90710	0.85210	2.21020	9.39120	11.50225	11.21479	5.17960	2.09110
28	0.73480	0.71930	1.98960	8.43870	10.89626	10.34100	4.82250	1.91650
29	0.56990	0.61190	1.75690	7.44650	10.10315	9.37323	4.46270	1.67590
30	0.42450	0.50960	1.58630	6.23400	9.35162	8.51664	4.16360	1.50550
31	0.32330	0.42250	1.37660	5.25570	8.67073	7.69027	3.88250	1.33930
32	0.25450	0.35130	1.23140	4.62970	8.05117	6.99289	3.61450	1.25880
33	0.20570	0.28710	1.03740	4.04320	7.47185	6.35175	3.35530	1.10900
34	0.16160	0.23260	0.87950	3.57300	6.95489	5.77942	3.16090	0.99930
35	0.12280	0.19510	0.76560	3.08340	6.53957	5.31519	2.96090	0.91570
36	0.08500	0.15280	0.64740	2.84270	6.18244	4.93705	2.80890	0.83400
37	0.05940	0.12170	0.53270	2.62690	5.80680	4.57118	2.63720	0.74500
38	0.04270	0.10080	0.47070	2.36780	5.43984	4.21436	2.49740	0.64390
39	0.03890	0.08220	0.39600	2.01290	5.03562	3.87896	2.33310	0.52730
40	0.02760	0.06780	0.34560	1.74640	4.78049	3.65020	2.18970	0.42780
41	0.02200	0.05430	0.29570	1.52880	4.57138	3.40416	2.07770	0.35540
42	0.01700	0.04580	0.25290	1.38680	4.29565	3.17241	1.96170	0.31320
43	0.01210	0.03670	0.21810	1.30380	4.04261	2.94534	1.85750	0.28850

Separation	Non-Work Trip Purpose F-Factors							
	HBNW-ED1	HBNW-Retail	HBNW-Other	HBNW-Airport	NHB-Work	NHB-Other	Truck	Taxi
44	0.00940	0.02970	0.18370	1.19130	3.84461	2.74196	1.77890	0.26930
45	0.00770	0.02450	0.15950	1.09630	3.65909	2.59477	1.67590	0.25360
46	0.00580	0.01990	0.13660	1.00870	3.47496	2.44543	1.59710	0.22760
47	0.00420	0.01610	0.11540	0.92940	3.27541	2.29295	1.51090	0.19860
48	0.00360	0.01300	0.10040	0.85750	3.09910	2.16625	1.43390	0.17210
49	0.00220	0.01020	0.08330	0.79110	2.95967	2.03598	1.35530	0.14790
50	0.00150	0.00830	0.07060	0.73030	0.00000	0.00000	1.28300	0.12460
51	0.00100	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
52	0.00060	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
53	0.00050	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
54	0.00030	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
55	0.00020	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
56	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000