METHODOLOGY AND ASSUMPTIONS OF CENTRAL TRANSPORTATION PLANNING STAFF REGIONAL TRAVEL DEMAND MODELING

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INTRODUCTION

The regional travel forecasting model set of the Central Transportation Planning Staff (CTPS) is based on procedures that have evolved over many years at CTPS. It follows the traditional four-step travel-modeling process of trip generation, trip distribution, mode choice, and trip assignment and is implemented in the EMME software package. This modeling process is employed to estimate present and future average weekday transit ridership and average weekday highway traffic volumes, primarily on the basis of demography and the characteristics of the transportation network. The model set simulates travel on the entire eastern Massachusetts transit and highway systems. When the model set is estimating future travel, the inputs include forecasts of demography and projections of transit and highway improvements.

This document describes in detail the model set developed for the Kendall Square Mobility Task Force Project. The model set will generally be referred to as “the model,” for simplicity’s sake. The organization of this document is:

OVERVIEW OF THE FOUR STEPS

In the first step, the total number of trips produced by residents of the CTPS Modeling Area (the 101 cities and towns that make up the Boston Region Metropolitan Planning Organization [MPO] area, together with 63 Eastern Massachusetts communities outside of the MPO area) is calculated using demographic and socioeconomic data and trip production rates estimated from household travel survey data. Similarly, the number of trips attracted to different types of land use, such as employment centers, schools, hospitals, shopping centers, etc., is estimated using land use data and trip generation rates obtained from household travel surveys. This information is produced at the level of disaggregated geographic areas known as transportation analysis zones (TAZs). All calculations are performed at the TAZ level.

In the second step, trip distribution, the model combines each trip production with a trip attraction to form a trip, resulting in the distribution of the trips produced in each TAZ throughout the region. Trips are distributed based on transit and highway travel times, distances, and costs between TAZs, on the relative attractiveness of each TAZ, which is measured by the number of trips attracted to that TAZ, and on the travel patterns recorded in household travel surveys.

Once the number of trips of each purpose between each pair of TAZs is determined, the mode choice step of the model (step three) allocates the trips among the available modes of travel. The available modes of travel are walk, auto (single-occupancy vehicle [SOV] and carpool), and transit (subdivided by access mode: walking to transit or driving to transit). To determine the proportion of trips to allocate to each mode, the model takes into account the travel times and distances, number of transfers required, parking availability, and costs associated with each option and how household travel surveys indicate they influence the modal choice. Other variables, such as auto ownership and household size, are also included in the model.

After estimating the number of trips by mode for each purpose for all possible TAZ combinations, the model assigns trips to their respective specific routes in trip assignment (the fourth and final step). This is necessary because there is almost always more than one highway route or transit path between two TAZs.

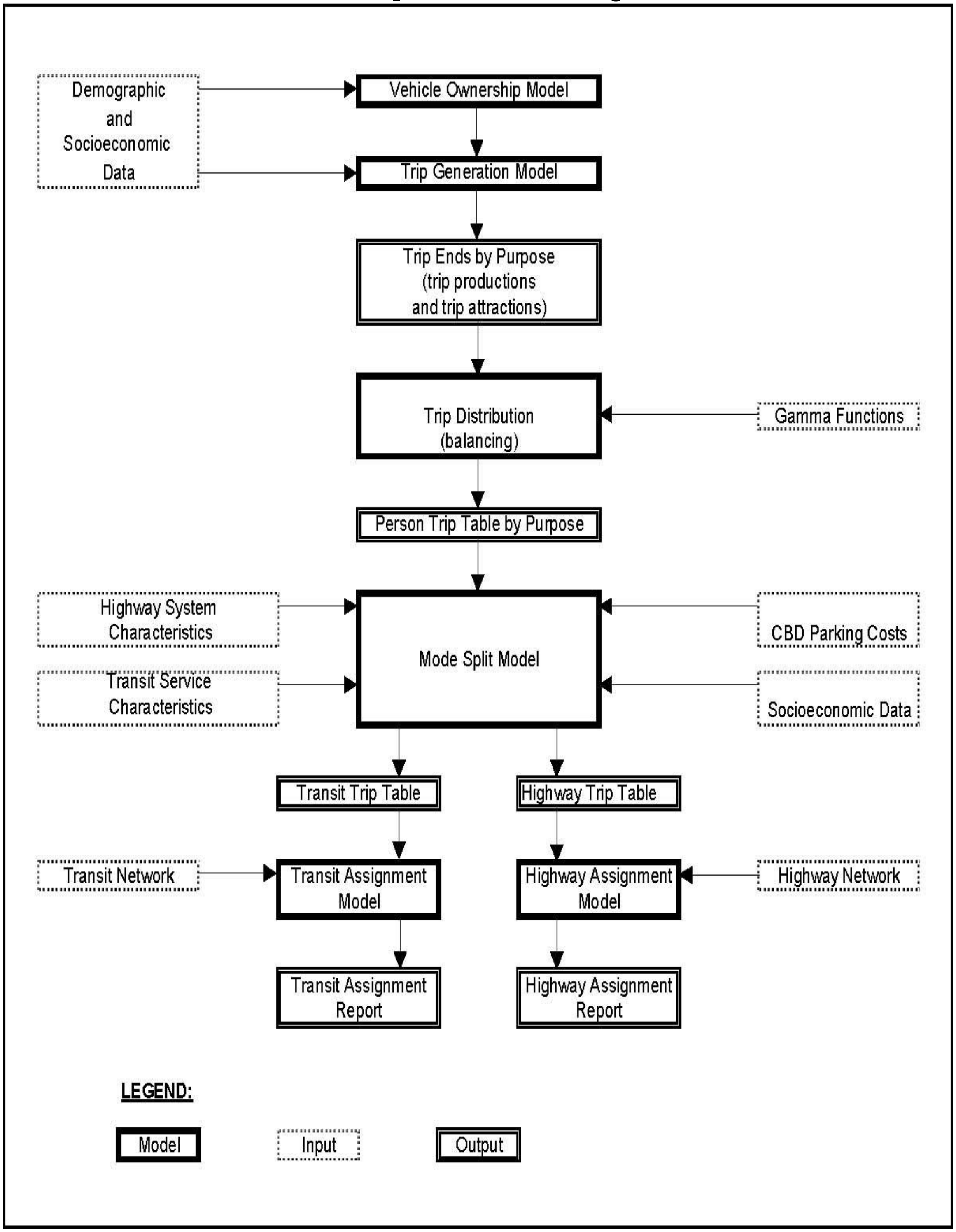
Various reports showing the transit ridership on different transit modes (including the specific ridership on each of the existing and proposed individual transit lines) and traffic volumes on the highway network are produced as needed. A schematic representation of the modeling process is shown in Figure 1.

NOTABLE FEATURES OF THE MODEL

The model developed for the Kendall Square Mobility Task Force Project uses the best component models, networks, and input data available to CTPS at this time. Some of the notable features of the model are as follows:

- It incorporates both motorized and non-motorized trips.
- It simulates transit and highway travel during four time periods of a typical weekday.

FIGURE 1
The Four-Step Demand Modeling Process



- The trip generation, trip distribution, and mode choice components are well calibrated.
- EMME software used in implementing the model is capable of performing a multi-class, multi-path assignment that is superior to the traditional all-or-nothing assignment.

MODEL STRUCTURES AND INPUTS

Modeled Area

The modeled area encompasses 164 cities and towns in eastern Massachusetts, which includes the 101 Boston Region MPO cities and towns and 63 additional communities, as shown in Figure 2. The figure also shows the boundaries of five concentric rings into which the modeled area is divided for model estimation and calibration purposes. These rings will be referred to in subsequent discussions.

Zone System

The modeled area is divided into 2,727 internal TAZs. There are 124 external stations around the periphery of the modeled area that allow for travel between the modeled area and adjacent areas of Massachusetts, New Hampshire, and Rhode Island.

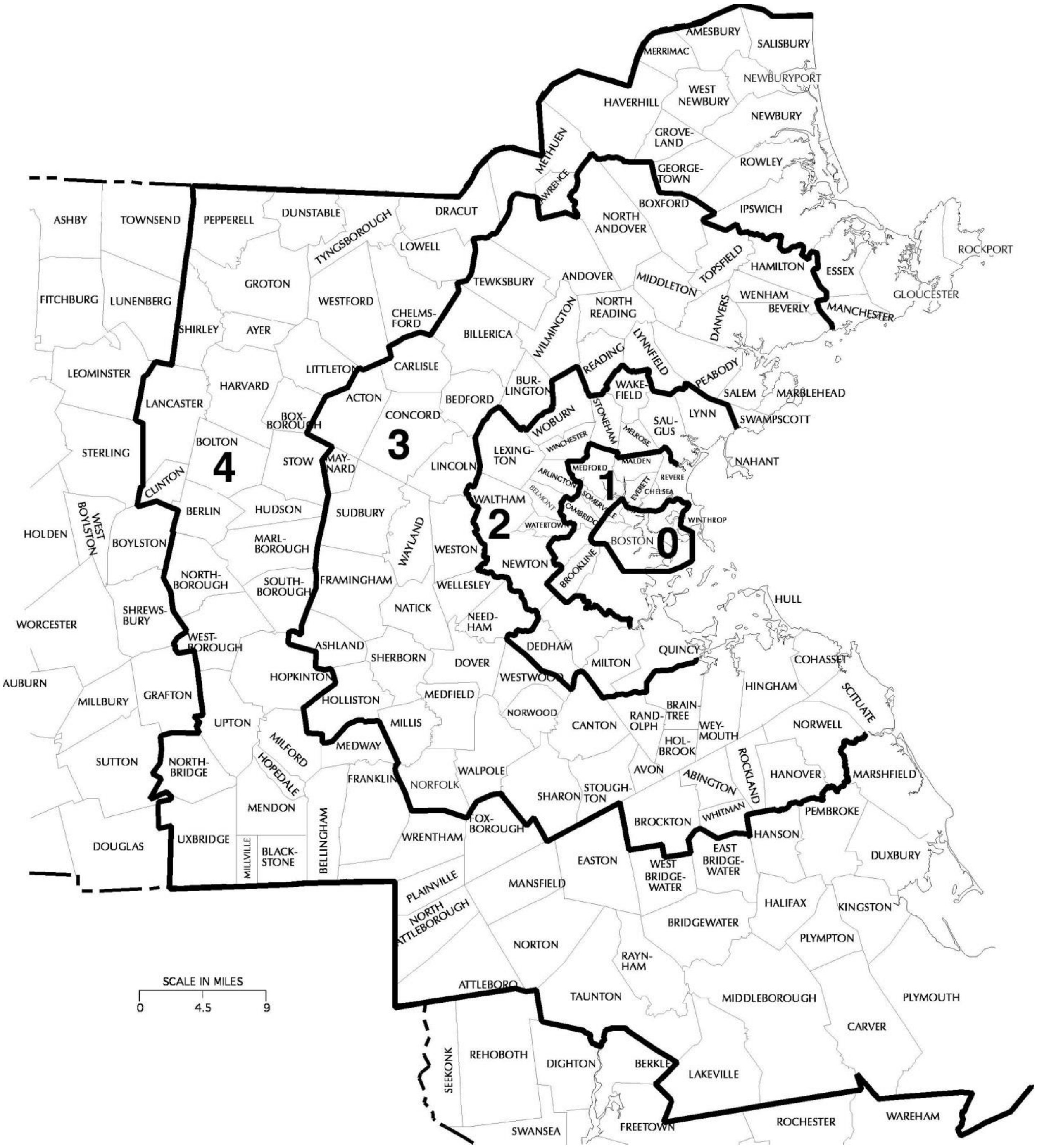
Transportation Networks

The transit and highway networks are integrated into one transportation network in EMME. The highway network component comprises express highways, principal and minor arterials, and local roadways. The transit network component comprises commuter rail lines, rapid transit lines, bus lines (MBTA and private carriers), free shuttles, and boat lines. The model contains service frequency (how often trains and buses run), routing, travel time, and fares for all lines.

- *Highway Network*: The regional highway network contains in excess of 40,000 links and 15,000 nodes. It is fairly dense in the study area, although, like any modeled network, it does not include some local and collector streets. Each link is coded with the appropriate free-flow speed (generally, the speed limit), number of lanes, and lane capacity. Functional class is coded, as are various geographic flags useful for summarizing emissions. Another code is used to distinguish which modes (SOV, HOV, pickup/van, hazardous materials, or other truck) each link is open to.

- *Transit Network*: The transit network represents all regional transit agency bus, rail, and boat services in eastern Massachusetts, as well as free shuttle buses and private express buses. Most-likely travel paths are built through the network, and the resulting impedances (travel times, distances, and costs) are used as inputs to the trip distribution and mode choice models. After mode choice, transit trip tables by time of day are assigned to the network travel paths.

FIGURE 2
CTPS Modeled Area and Ring Boundaries



Major Data Inputs

CTPS's travel model underwent a major revision in 1993, and several important data sources were used in that revision. More recent data that has been developed or become available over the past two decades have been used to bring the model up to 2012 conditions. These major data items underlying the model are as follows:

- *Household Travel Survey:* In 1991, CTPS conducted a household travel survey. The survey took the form of an activity-based travel diary that each subject household filled out for one weekday. Approximately 4,000 households, generating some 39,000 weekday trips, were represented in the final database. The data were used to estimate new models for trip generation, auto ownership, trip distribution, and mode choice.

- *External Cordon Survey:* Also in 1991, a survey of automobile travelers bound for the modeled area from adjacent areas was performed. Survey results were used in trip generation and distribution to update estimates of external trips.

- *Site-Level Employment Database:* Employment estimates for 2000 were taken from a single, unified regional employment database based on employment data from the Department of Employment and Training and on extensive research by CTPS. Aggregate employment data for the year 2009 were used to update this database for use for the base-year analysis in the regional model version used for this study.

- *2000 and 2010 U.S. Census:* Various files from the 2000 and 2010 US Census (population, households, and group quarters) were used in model estimation and calibration processes. In addition, Census Journey-to-Work information from the American Community Survey was incorporated into the model at several stages of model development. Aggregate population and employment estimates for the year 2012 were used to update this data for this study.

- *Ground Counts:* Transit ridership and highway traffic volume data representing early 1990s conditions were amassed into a database and used to calibrate the components of the travel model. Updated counts and volumes, collected between 2005 and 2012, have been used for model validation.

- *On Board Transit Passenger Survey:* CTPS surveyed passengers on all MBTA transit modes in an effort spanning the years 2008-2010. Data from this survey, specifically for transit service in the study area, were used to validate and calibrate components of trip distribution and mode choice for the model.

- *Updated Employment, Population, and Gas Prices*: The trip tables produced by the Trip Generation and Trip Distribution models represent the year 2012. These are brought up to 2012 by applying the changes in the Boston area Consumer Price Index, Boston area gasoline price, Eastern Massachusetts town residential populations, Eastern Massachusetts town residential workers, and Eastern Massachusetts town employment. The square root of the ratio of 2011 Eastern Massachusetts town residential populations to 2009 is applied to all the rows of the trip tables (with the exception of the square root of the ratio of the 2012 Eastern Massachusetts town residential workers to 2009 applied to all the rows of the home-based work trip table). The square root of the ratio of 2012 Eastern Massachusetts town employment to 2009 is applied to all the columns of the trip tables. The 2012 CPI and gas price are used to adjust the auto operating costs and the effective level of other costs in the mode choice and assignment models.

Analysis Year

The base year is 2012, the opening year is 2020, and the forecast horizon year is 2040.

Time-of-Day Considerations

The mode choice and transit assignment steps of the modeling process are conducted on the basis of time periods. The four time periods modeled are an AM peak period (6:00 AM–9:00 AM), a midday period (9:00 AM–3:00 PM), a PM peak period (3:00 PM–6:00 PM), and a nighttime period (6:00 PM–6:00 AM). The trip generation model, however, is based on daily trips. The trip distribution model considers two time periods: peak (the AM peak and PM peak periods) and off-peak (the midday and nighttime periods).

The trip volumes produced by the trip generation model are split into peak and off-peak period trips, the trip tables produced by the trip distribution model are split into the four time periods defined above, and the highway vehicle trips and transit person trips created by the mode choice model are converted from production/attraction format to an origin/destination format, based upon factors created from the data collected in the 1991 Household Travel Survey. The PM peak period apparently spread into the nighttime period between 1991 and 2012, so 15% of the PM peak period highway trips are moved to the nighttime period after the mode choice model is run and before the trip tables are assigned to the network.

The final trip tables created for each time period reflect observed levels of congestion on the highway system. The results of the four assignments are summed to obtain average weekday traffic (AWDT) results.

Population, Household, and Employment Forecasts

Households and employment by type are major inputs to the travel model process: they are the variables upon which trip generation is performed. The forecasts for the region were developed by combining household and employment forecasts produced independently by the seven regional planning agencies (RPAs) in eastern Massachusetts: the Central Massachusetts Regional Planning Commission (CMRPC), Merrimack Valley Planning Commission (MVPC), Metropolitan Area Planning Council (MAPC), Massachusetts Regional Planning Commission (MRPC), Northern Middlesex Council of Governments (NMCOG), Old Colony Planning Council (OCPC), and Southeastern Regional Planning and Economic Development District (SRPEDD). Forecasts for the 101 cities and towns that make up the Boston Region MPO area were developed by MAPC based on a scenario it has developed, known as the MetroFuture scenario, in which growth was targeted to communities' denser areas, with a focus on development around transit stations.

Employment base year estimates were developed in a different fashion than population and household estimates. CTPS examined the annual employment estimates produced by the state's Division of Employment and Training (DET). Differences in employment between 2000 and April 2008 were calculated at the town level for the region. These differences were then applied to the Boston Region MPO's year 2000 town level data and then distributed among each town's TAZ system according the year 2000 employment distribution. The realm of "basic" employment was refined according the extensive up-to-date manufacturing employment database maintained by CTPS. Thus, these sources were utilized to best reflect the reality of employment throughout the model area's geography in 2012. Future year (2040) employment projections for the region were taken from the MetroFuture scenario.

Forecasts for the 63 communities in the model belonging to RPAs other than MAPC were developed in a slightly different fashion. Each RPA independently maintains its own travel demand model, TAZ system, base-year estimates, and future-year forecasts. However, the Boston Region MPO's data have long been accepted as the best possible and most refined and detailed demographics data set for eastern Massachusetts, and significant faith has been invested in it.

This combination of forecasts ensured the accuracy of the Boston Region MPO's widely accepted demographic data sets while still capturing and respecting much of the growth expressed and projected by the individual RPAs for the other 63 communities.

TRIP GENERATION

The first step in the travel forecasting process is performed by the model set's trip generation model. This model uses socioeconomic characteristics of the region's population and information about the region's transportation infrastructure, transportation services, and geography to predict the amounts of travel that will be produced by and attracted to each of the TAZs within the region.

The trip generation model is composed of seven parts:

- Base-year detailed inputs
- Future-year inputs
- Estimation of detailed input requirements for future years
- Estimation of detailed socioeconomic characteristics
- Estimation of vehicle ownership
- Estimation of trip productions and attractions
- Balancing of trip productions and attractions

A description of each of these parts is presented below.

Base-Year Detailed Inputs

The base-year inputs required for the trip generation model are presented in Table 1. Please note that although the base-year trip generation model produces results for 2009, as aforementioned, these results are subsequently factored using a Fratar process following the trip distribution model procedures to produce 2012 trip tables.

TABLE 1
Trip Generation Model: Base-Year Input Requirements

Data	Source	Geographic Level
Population	2012 estimates	TAZ (census block)
Group Quarters Population	2012 estimates	TAZ (census block)
Household Size, Income, Workers, Vehicles	2012 estimates	TAZ (census block)
Population Age	2012 estimates	City or town
Basic, Retail, Service Employment	2012 estimates	TAZ
Public K-12 Employment	2012 estimates	TAZ
Private K-12 Employment	2012 estimates	TAZ
College Employment	2012 estimates	TAZ
Resident Workers	2012 estimates	TAZ (census block group)
Dorm Population	2012 estimates	TAZ (census block)
Labor Participation Rate by Age Group	Bureau of the Census	Region
Land Area	CTPS regional database	TAZ
Geographical Ring	CTPS regional database	TAZ
Public Use Microdata Areas	CTPS regional database	Public Use Microdata Areas
External Trip Productions and Attractions	1991 External Travel Survey, 2010 U.S. Census	External station
External Growth Factors	RPA and CTPS forecasts	External station
Transit Walk Access Factor	Transit network	TAZ
External Attraction and Production Terminal Times	1991 External Travel Survey	External station

Future-Year Inputs

The future-year inputs required for the trip generation model, some of which are the same as for the base year, are:

- Total TAZ households
- Total TAZ population
- Total TAZ group quarters population
- Total community population by age
- TAZ employment in basic industries
- TAZ retail trade employment
- TAZ employment in service industries
- Regional labor participation rates
- External trip production and attraction growth factors
- Transit walk-access factors

Estimation of Detailed Input Requirements for Future Years

Various procedures are used to prepare the trip generation model input data for future years. The variables that are estimated in these procedures are listed below. A description of how future-year estimations for these variables are made follows the list.

- Households by household size
- Households by income quartile
- Resident workers
- Households by workers per household
- School employment (K-12 and college)
- Dorm population
- External person trips
- Attraction and production terminal times

Household Size

The change in TAZ average household size is implied in the base-year inputs and future-year forecasts (total population minus group quarters population divided by total households). The distribution of future-year households by household size is estimated by the following procedure:

First, the future-year households are distributed among the household size categories in the same proportions as in the base year. It is then assumed that all households capable of making the implied change (households of two or more for household size reductions; all households for household size increases) will have the same probability of changing in size by one person. This probability of changing is set equal to the extent needed to match the forecasted change in household size, and the resulting distribution of households by household size is used for the future-year scenario.

As an example, suppose that in the base year the numbers of 1-person, 2-person, 3-person, 4-person, 5-person, and 6+-person households are, respectively, 100, 200, 50, 25, 10, and 5, with a total household population of 835. This represents an average household size of 2.141 for the 390 households. If there were 780 future-year households, they would initially be distributed as 200, 400, 100, 50, 20, and 10 1-person, 2-person, 3-person, 4-person, 5-person, and 6+-person households, respectively.

However, if the future-year average household size were estimated to be lowered to 2.000, then the households with 2 or more persons would have a 19 percent [(2.141 – 2.000) * 780/580] probability of dropping in size by one, as an average of .141 persons must be dropped from the 780 households, but they can only come from among the 580 households initially having 2 or more members. The resulting distribution would thus be estimated as follows:

276 1-person households [200 + (.19 * 400)] (19 percent of the 2-person households would lose a member and become additional 1-person households)
343 2-person households [400 – (.19 * 400) + (.19 * 100)] (19 percent of the 2-person households would lose a member and leave the 2-person household category while 19 percent of the 3-person households would lose a member and become additional 2-person households)
90.5 3-person households [100 – (.19 * 100) + (.19 * 50)]
44.3 4-person households [50 – (.19 * 50) + (.19 * 20)]
26.2 5+-person households [20 – (.19 * 20) + 10]

In the case of TAZs with no households in the base year, if they have households in another scenario, the proportional distribution of those households by household size is assumed to be the same as it is at the community level.

Household Income

The future-year distribution of households by household income quartile is estimated by assuming that the proportional distribution of households by income quartile remains constant within each TAZ. In the case of TAZs with no households in the base year, the proportional distribution of households by household income at the community level is used for the base year.

Resident Workers per Household

The change in the number of resident workers at the community level is obtained by multiplying the base-year and future-year estimates of over-age-15 population by labor force participation rates by age cohort. Dividing the base-year and future-year estimates of community-level resident workers by the base-year and future-year numbers of households in the community, respectively, produces estimates of the base-year and future-year average workers per household. All of the TAZs within each community are assumed to have the proportional change in workers per household implied by these base-year and future-year community-level estimates. Multiplying the resultant estimate of resident workers per household by the forecasted number of households yields the forecasted number of resident workers by TAZ.

For example, assume that a community's 2012 and 2040 populations are distributed by age as follows: 1,000 and 1,200, 10,000 and 11,000, 2,000 and 2,500, and 500 and 600, respectively, in the 16-24, 25-54, 55-64, and 65+ age ranges. If the applicable labor force participation rates are applied (see Table 2), the estimated numbers of community resident workers become 10,157 and 11,529 for 2012 and 2040, respectively. If the estimated numbers of community households were 5,500 and 6,000 for 2012 and 2040, respectively, the community average workers per household for 2012 and 2040 would be 1.85 and 1.92, respectively. As 1.92 is 3.8% greater than 1.85, all of the TAZs in that community would be assumed to have a 3.8% increase in workers per household between 2012 and 2040.

TABLE 2
Labor Force Participation Rates

Age	2012	2040
16-24	55.2%	58.5%
25-54	82.2%	81.5%
55-64	64.9%	68.9%
65+	17.4%	27.7%

Household Workers

The future-year number of households per TAZ within each category of number of workers per household is estimated by using workers-per-household distribution curves developed by CTPS from the 1990 U.S. Census. These curves, summarized in Table 3 below, indicate a default percentage distribution of households for the base-year and future-year TAZ estimates of average workers per household. The proportional changes in the default number of households within each category of workers per household implied by this comparison are applied to the actual base-year TAZ distribution of households to obtain the distribution of households by workers per household to be used for the future scenario. The average number of workers per household at the community level is used for the base year in TAZs with no households in the base year.

For example, if the average number of workers per household changes from 1.7 to 1.8, the default distribution of households among the categories 0-worker, 1-worker, 2-worker, and 3+-worker would change from 7%, 32%, 45%, and 16% to 5%, 29%, 47%, and 19%, respectively. If the actual base-year distribution of households among those categories is 8%, 31%, 44%, and 17%, the changes in the default distributions indicate a future-year distribution of households of 6%, 28%, 46%, and 20% 0-worker, 1-worker, 2-worker, and 3+-worker households, respectively.

School Employment

- K-12

  The level of employment in schools providing education up to the 12th grade is assumed to change by the same proportion as the number of community residents of ages 5-19.

- College

  The level of employment at all colleges and technical schools within the region is assumed to change by the same proportion as the number of regional residents of ages 20-24.

TABLE 3
Workers per Household Diversion Curves

Avg. Workers per HH	Households by Number of Workers				
	0	**1**	**2**	**3+**	**Total**
<=.45	58%	40%	2%	0%	100%
.45 - .55	52%	46%	2%	0%	100%
.55 - .65	47%	46%	6%	1%	100%
.65 - .75	43%	46%	10%	1%	100%
.75 - .85	38%	46%	13%	3%	100%
.85 - .95	34%	46%	16%	4%	100%
.95 - 1.05	30%	45%	20%	5%	100%
1.05 - 1.65	65% - (35% * Avg Wrk/HH)	60% - (16% * Avg Wrk/HH)	(36% * Avg Wrk/HH) - 15%	(15% * Avg Wrk/HH) - 10%	100%
1.65 - 1.75	7%	32%	45%	16%	100%
1.75 - 1.85	5%	29%	47%	19%	100%
1.85 - 1.95	4%	26%	48%	22%	100%
1.95 - 2.05	3%	22%	48%	27%	100%
2.05 - 2.15	2%	18%	49%	31%	100%
2.15 - 2.25	1%	14%	49%	36%	100%
2.25 - 2.35	1%	10%	49%	40%	100%
2.35 - 2.45	1%	4%	50%	45%	100%
2.45 - 2.55	1%	4%	50%	45%	100%
> 2.55	0%	5%	50%	45%	100%

Dorm Population

The dorm population within a TAZ is assumed to remain the same proportion of the total group quarters population within a TAZ.

External Person Trips

Base-year external person trips are adjusted to produce traffic volumes at the external stations that match the observed counts for the base year. These base-year external person trips are then adjusted according to growth factors for the vehicle volumes at each external station. These growth factors are presently based upon an analysis of historical trends.

Attraction and Production Terminal Times

The attraction and production terminal times (the time it takes to travel between a vehicle and the trip origin or destination) are estimated through the application of a model developed at CTPS. This model first estimates terminal times as a function of household density (see Table 4). An alternative estimate of the production and attraction terminal times for each TAZ is based on employment density ranges (see Table 5). For regional modeling, the larger of the two estimates is assigned to a TAZ. Several TAZs with regionally unique characteristics (locations of major generators such as airports or large colleges) were assigned terminal times in the base year different from those estimated by the terminal-time model. In these cases, the model is used to estimate changes in terminal times.

TABLE 4
Household Terminal Time

Household Density (HH per acre)	Production (minutes)	Attraction (minutes)
0 – 5	1	1
5 – 10	2	2
10 – 15	3	3
15 – 25	4	4
> 25	5	5

TABLE 5
Employment Terminal Time

Employment Density (employees per acre)	Production (minutes)	Attraction (minutes)
0 – 5	0	1
5 – 10	1	2
10 – 25	2	3
25 – 50	3	4
50 – 100	4	5
100 – 200	5	6
> 200	6	7

Estimation of Detailed Socioeconomic Characteristics

A three-way distribution of the households within each TAZ by household size, income, and workers is required in order to estimate the distribution of households by vehicle ownership levels. While this is available from the U.S. Census at the subregional level, such distributions at the TAZ level are estimated through iterative proportional fitting techniques. Using the appropriate subregional matrix as a seed, the cell values are adjusted through 10 iterations to match totals as closely as possible to the estimated TAZ-level totals of households by household size, income, and workers in order to produce an estimated three-way distribution of households for each TAZ.

Estimation of Vehicle Ownership

Base-year households are distributed by vehicle ownership based on data from the 2010 American Community Survey. The distribution of future-scenario households by vehicle ownership is estimated through the application of a set of models developed by CTPS.

The CTPS vehicle ownership model was estimated as a set of four multinomial logit disaggregate choice models, one for each of four income categories, in which the decision maker was the household unit and the set of alternatives was the ownership, by the household, of 0, 1, 2, or 3-or-more vehicles. Households are segmented into the four income categories in these models, since income is believed to be the most significant variable in vehicle-ownership choice. Other variables included in the model are household size, workers per household, household density, employment density, household location, and transit walk-access factors. The data set used to estimate this model contained 3,504 observations. Once estimated, the model was validated to observed vehicle ownership data. The models are presented in Table 6.

Estimation of Trip Productions and Attractions

The number of trip productions and trip attractions within a TAZ are estimated through the application of a set of models developed at CTPS. These models estimate the number of trip productions and attractions as a function of household size, workers per household, vehicles per household, income, household location, number of households, basic employment, retail employment, college employment, school employment, and service employment. The trip production models for the home-based purposes [home-based work (HBW), home-based work-related (HBWR), home-based personal business (HBPB), home-based social-recreational (HBSR), home-based school (HBSC), and home-based pick-up/drop-off (HBPD)] are presented in Table 7, and the trip production models for the non-home-based purposes [non-home-based work (NHBW) and non-home-based-other (NHBO)] and the trip attraction models for all purposes are presented in Table 8.

TABLE 6
Summary of Vehicle Ownership Model

	Constant	HH Size	Workers per HH	HHs per Acre	Employ per Acre	High-Density	Low-Density	Ring01	Transit Walk-Accessibility
Low-Income Household Model									
0 Vehicles	-0.0474	-0.1692	-0.1312	0.0239		0.7136			
1 Vehicle									
2 Vehicles	-3.139	0.6182	0.4414	-0.0424					
3+ Vehicles	-5.074	0.7968	0.6927	-0.2232					
Medium-Low-Income Household Model									
0 Vehicles	-1.573	-0.1874	-0.3417	0.05		0.5716		0.5392	
1 Vehicle									
2 Vehicles	-1.745	0.5202	0.4279	-0.0627	-0.0334				-0.0056
3+ Vehicles	-5.101	0.7371	1.112	-0.0627	-0.0693				
Medium-High-Income Household Model									
0 Vehicles	-2.63			0.0459		0.7704			
1 Vehicle									
2 Vehicles	-1.223	0.6609	0.2377	-0.0391			0.4026	-0.5962	-0.0054
3+ Vehicles	-4.572	0.7899	1.289	-0.0779				-1.223	-0.0073
High-Income Household Model									
0 Vehicles	-2.793			0.0349					
1 Vehicle									
2 Vehicles	0.5049	0.3475	0.2688	-0.06	-0.0154				-0.0074
3+ Vehicles	-3.807	0.5717	1.628	-0.136	-0.0468				-0.0077

High-Density = 1 if HH/acre > 6 or Employ/acre > 7
Low-Density = 1 if HH/acre < 0.5 and Employ/acre< 0.7
Ring01 = 1 if TAZ is in Ring 0 or Ring 1
Transit Walk-Accessibility = Portion of TAZ within walk-access distance of transit service

Balancing of Trip Productions and Attractions

Connecting a trip production with a trip attraction of the same trip purpose forms a trip. As a result, the number of productions and attractions for each trip purpose must be equal. In order to achieve this, the trip productions and attractions are balanced.

For most trip purposes, the number of regional attractions is the least reliable estimate. Therefore, the normal balancing procedure is to set the total number of regional attractions equal to the difference between the grand total of productions and the total number of external attractions.

TABLE 7
Home-Based Trip Production Rate Models

Home-Based Work Trip Production Rates

Workers per HH	HH Size	Vehicles per HH 0	1	2+
1	*1*	0.94	1.17	1.11
1	*2*	1.01	1.23	1.18
1	*3*	1.15	1.38	1.32
1	*4*	1.48	1.70	1.65
1	*5+*	1.56	1.78	1.71
2	*2*	2.47	2.66	2.47
2	*3*	2.64	2.81	2.61
2	*4*	2.68	2.84	2.64
2	*5+*	2.83	2.99	2.79
3+	*3*	2.72	3.14	3.68
3+	*4*	2.75	4.02	4.55
3+	*5+*	2.88	4.15	4.68

Home-Based Personal Business Trip Production Rates

Workers per HH	HH Size	Vehicles per HH 0	1	2	3+
0	*1*	1.19	1.95	2.11	2.87
0	*2*	2.91	3.32	3.50	4.24
0	*3*	3.29	3.70	3.88	4.62
0	*4*	4.16	4.58	4.73	5.49
0	*5+*	1.56	4.71	4.87	5.63
1	*1*	0.50	1.01	1.20	1.27
1	*2*	1.85	2.35	2.55	2.62
1	*3*	2.25	2.82	3.04	3.11
1	*4*	2.52	2.91	3.08	3.13
1	*5+*	2.55	2.93	3.15	3.23
2	*2*	1.04	1.50	1.63	2.12
2	*3*	1.40	1.87	1.99	2.48
2	*4*	2.37	2.83	2.95	3.45
2	*5+*	2.44	2.91	3.03	3.52
3+	*3*	1.43	1.96	2.24	2.49
3+	*4*	2.00	2.75	3.14	3.49
3+	*5+*	2.34	3.20	3.67	4.08

HB Work-Related Trip Production Rates

HH Size	Workers per HH 1	2	3+
1	0.12		
2	0.10	0.18	
3	0.10	0.20	0.28
4	0.18	0.23	0.35
5+	0.21	0.29	0.41

TABLE 7 (cont.)
Home-Based Trip Production Rate Models

Home-Based School Trip Production Rates

	HH	Household Income Quartile			
Ring	**Size**	**Low**	**Med-low**	**Med-high**	**High**
0 & 1	*1*	0.20	0.12	0.08	0.06
0 & 1	*2*	1.22	0.56	0.28	0.26
0 & 1	*3*	1.82	1.42	0.51	0.51
0 & 1	*4*	2.53	1.82	1.77	1.72
0 & 1	*5+*	5.07	4.05	3.04	2.53
2	*1*	0.15	0.03	0.02	0
2	*2*	0.41	0.18	0.13	0.05
2	*3*	1.30	0.92	0.35	0.25
2	*4*	2.01	1.55	1.47	1.19
2	*5+*	2.57	2.28	2.11	2.06
3 & 4	*1*	0.01	0.04	0.04	0.02
3 & 4	*2*	0.06	0.25	0.05	0.04
3 & 4	*3*	0.54	0.41	0.41	0.41
3 & 4	*4*	0.90	1.07	1.02	0.97
3 & 4	*5+*	1.35	2.53	2.24	1.85

HB Social/Recreational Trip Production Rates

HH	Workers per Household			
Size	**0**	**1**	**2**	**3+**
1	0.88	0.70		
2	1.79	1.13	1.17	
3	1.79	1.49	1.68	2.24
4	2.02	1.95	2.14	2.87
5+	3.58	3.50	3.85	3.94

HB Pick-up/Drop-off Trip Production Rates

HH	Vehicles per Household			
Size	**0**	**1**	**2**	**3+**
1	0.04	0.04	0.04	0.04
2	0.10	0.22	0.13	0.13
3	0.30	0.41	0.36	0.28
4	0.36	0.58	1.07	0.42
5+	0.85	1.73	1.58	1.08

TABLE 8
Trip Attraction Rates and Non-Home-Based Trip Production Rates

	Households	Basic Employment	Retail Employment	Service Employment College	Service Employment K-12	Service Employment Other
			Production Rate Models			
Non-Home-Based Work	0.07	0.47	1.78	1.86	0.93	0.93
Non-Home-Based Other	0.57		1.74	2.49	0.28	0.28
			Attraction Rate Models			
Home-Based Work		1.42	1.64	1.23	1.23	1.23
Home-Based Work-Related		0.06	0.35	0.27	0.08	0.08
Home-Based Personal Business	1.25		4.17			
Home-Based Social/Recreational	1.28		1.34	1.13		
Home-Based School				3.30	9.25	
Home-Based Pick-Up/Drop-Off	0.13	0.04	0.04	0.04	4.25	0.04
Non-Home-Based Work	0.11	0.32	2.36	1.85	0.79	0.79
Non-Home-Based Other	0.59		1.91	2.01	0.22	0.22

However, more information is available about regional patterns for the home-based work (HBW) trip during the base year. In order to produce base-year home-based work trip ends that reflect the observed patterns, the following changes are made as part of the base-year balancing procedure:

- Total regional HBW attractions are adjusted to match the base year ratio of total regional HBW attractions to total regional HBW productions with the estimated ratio from the 2010 American Community Survey (1.0767).
- Total external HBW attractions are adjusted to match the base-year ratio of total external HBW attractions to total regional HBW productions with the estimated ratio from the 2010 American Community Survey (.0486).
- Total external HBW productions are set equal to the difference between the grand total of HBW attractions and the regional HBW productions.

In addition, forecasts of future regional employment (the determinant of home-based work trip regional attractions) are available, so the estimates of future external HBW productions and attractions are less reliable than the estimates of future regional HBW productions and attractions. The model assumes that the number of external HBW productions will satisfy the forecasted employment within the region, so the HBW external productions are set equal to the difference between the total HBW attractions and the regional HBW productions.

TRIP DISTRIBUTION

The trip distribution model performs the second step in the travel forecasting process. It combines the estimated trip productions and trip attractions prepared by the trip generation model (combining the HBW and HBWR purposes into a new HBW purpose) into

- an interregional vehicle trip table and an intraregional pick-up/drop-off vehicle trip table, to be used as input into the highway assignment model, and
- intraregional person trip tables to be used as inputs into the mode choice model.

The trip distribution model is made up of three components: a set of internal-external trip distribution models and two sets of intraregional trip distribution models (one for peak travel periods and the other for non-peak travel periods). An overview of the model is presented below.

Internal-External Trip Distribution

Internal-external trip distribution refers to a process in which all internal and external average weekday (AWD) trip ends (trip productions and attractions) are combined into trips using AWD highway impedances, but only the trips with one end in an internal zone and the other end in an external zone are retained. The resultant internal-external/external-internal trip tables are used as inputs to the highway assignment model. The remaining trip ends are used as inputs to the intraregional trip distribution model.

The model includes a separate process for each of seven trip purposes: home-based work, home-based personal business, home-based social/recreational, home-based school, home-based pick-up/drop-off, non-home-based work, and non-home-based other. The process undertaken for each purpose consists of the following five steps:

- Convert highway travel times from time period origin-destination format to AWD production-attraction format
- Estimate and apply gamma functions to create an initial trip table estimate
- Initiate a three-dimensional balancing process, adjusting the initial trip table to match trip productions, trip attractions, and a trip-length frequency distribution
- Create internal-external/external-internal vehicular trip tables
- Create intraregional person trip table productions and attractions

Each of these steps is described below.

Conversion of Highway Travel Times

Estimates of highway travel times are prepared using the highway assignment model on an origin-destination basis for each time period. In order to use these estimates with the trip productions and attractions from the trip generation model, the estimates from origin TAZ to destination TAZ and from destination TAZ to origin TAZ produced by the highway assignment are combined for each trip purpose based upon temporal directional factors developed for each trip purpose from the 1991 regional household travel survey.

Estimation and Application of Gamma Functions

Interregional gamma functions are estimated using linear regression fitting to reflect the relationship between base-year highway travel time estimates and survey trip tables. These functions are used to provide an estimate of the number of trips within each cell of the trip table for a future scenario based upon the highway travel times for that future scenario.

The resultant trip table is referred to as the seed trip table. A trip length frequency distribution is imposed upon the seed trip table by dividing the table into classes of zone pairs. The zone pairs within each class connect a common pair of districts (forming an "interchange") and fall within a designated range of trip lengths (or "class"). A separate gamma function is used for each interchange. The number of interchanges and classes used for each trip purpose is presented in Table 9.

TABLE 9
Number of Interchanges and Classes Used for Each Trip Purpose

	Internal-External		Intraregional Peak		Intraregional Non-Peak	
Trip Purpose	**Interchanges**	**Classes**	**Interchanges**	**Classes**	**Interchanges**	**Classes**
HBW	36	250	36	250	36	250
HBPB	36	250	34	233	36	247
HBSR	35	247	33	225	36	242
HBSC	24	229	16	216	16	225
HBPD	25	243	4	49	4	51
NHBW	36	250	36	250	36	249
NHBO	25	246	33	227	36	249

Three-Dimensional Balancing

The seed trip table is adjusted through an iterative process in order to match its subtotals as closely as possible to the estimated trip productions, trip attractions, and trip length frequency distribution. Each iteration consists of adjusting all the cells within a dimension (row, column, or class) by the factor needed to match the sum of that dimension to the estimated subtotal in that dimension (productions for row, attractions for column, trip length range trips for class) and then performing the same calculations for the other two dimensions. Since there is more confidence in trip production estimates than in the trip attraction or trip length frequency estimates, the iterative process ends with an exact matching of the trip table production totals to the input trip productions for each purpose.

Internal-External Trip Tables

The portions of the resultant trip table connecting external stations and regional TAZs are saved and adjusted for use in the highway assignment model. Vehicle occupancy data from the latest external travel survey are used to convert the person trips to vehicle trips. Temporal and directional factors from the latest external travel survey are then used to convert the trips from one matrix of AWD trips from production zone to attraction zone to four matrices of time period trips from origin zone to destination zone.

Intraregional Productions and Attractions

The portions of the resultant trip table connecting a pair of regional TAZs are summed by TAZ of production and TAZ of attraction for use in the Intraregional Trip Distribution Model. Data from the 1991 household travel survey are used to split these trip production and trip attraction files into peak-period and non-peak-period files.

Intraregional Trip Distribution (Peak and Non-Peak)

Intraregional trip distribution refers to a process in which all peak-period and non-peak-period intraregional trip ends are separately combined into trips using composite impedances from the mode choice model. The resultant peak and non-peak intraregional trip tables are used as inputs to the mode choice model and highway assignment model.

The model includes a separate process for each of seven trip purposes: home-based work, home-based personal business, home-based social/recreational, home-based school, home-based pick-up/drop-off, non-home-based work, and non-home-based other. Similar to the Internal-External Trip Distribution Model, the process undertaken for each purpose consists of the following three steps:

- Convert composite impedance estimates from time period to peak and non-peak format
- Estimate and apply gamma functions to create an initial trip table estimate
- Initiate a three-dimensional balancing process, adjusting the initial trip table to match trip productions, trip attractions, and a trip-length frequency distribution

The results of these steps are then processed to final form in the following two steps:

- Create pick-up/drop-off vehicular trip tables
- Create intraregional person trip tables

The five steps are described below.

Conversion of Composite Impedances

Estimates of purpose-specific composite impedances are prepared using the mode choice model for origin-destination TAZ pairs for each time period. In order to use these with the intraregional trip productions and attractions from the Internal-External Trip Distribution Model, the composite impedance estimates produced by the mode choice model are adjusted for production-attraction TAZ pairs for each trip purpose by temporal factors for each trip purpose from the 1991 regional household travel survey.

Estimation and Application of Gamma Functions

Intraregional gamma functions are estimated using linear regression fitting to reflect the relationship between base-year composite impedance estimates (the combined utilities for all modes from the mode choice models) and survey trip tables. These functions are used to provide an estimate of the number of trips within each cell of the trip table for a future scenario based upon the composite impedances for that future scenario.

The resultant trip table is referred to as the seed trip table. A trip length frequency distribution is imposed upon the seed trip table by dividing the table into classes of zone pairs. The zone pairs within each class connect a common pair of districts (forming an "interchange") and fall within a designated range of trip lengths (or "class"). A separate gamma function is used for each interchange. The number of interchanges and classes used for each trip purpose is presented in Table 9 (above).

Three-Dimensional Balancing

The seed trip table is adjusted through an iterative process to match its subtotals as closely as possible to the estimated trip productions, trip attractions, and composite impedance range frequency distribution. This process is the same as the one used in the Internal-External Trip Distribution Model. Since there is more confidence in trip production estimates than in the trip attraction or trip length frequency estimates, the iterative process ends with an exact matching of the trip table production totals to the input trip productions for each purpose.

Pick-Up/Drop-Off Vehicular Trip Tables

Since all trips for the home-based pick-up/drop-off purpose are assumed to be vehicular trips, the resultant trip tables for that purpose are converted directly to vehicular trip tables so that they can be used in the highway assignment model. Vehicle occupancy data from the 1991 household travel survey are used to convert the person trips to vehicle trips. Temporal and directional factors from the 1991 household travel survey are then used to convert the trips from matrices of peak-period and non-peak-period trips from production zone to attraction zone to matrices of time period trips from origin zone to destination zone.

Intraregional Person Trip Tables

The resultant trip tables for the other purposes are then prepared. Data from the latest household travel survey are used to split these peak-period and non-peak-period files into person trip tables for each time period. These trip tables are then used as inputs to the mode choice model.

MODE CHOICE

Overview

Mode choice is the third step in travel demand forecasting and in CTPS's regional travel demand model. It is the process in which the trips from distribution are assigned to the various available modes of the transportation network.

CTPS developed multinomial logit mode choice models by trip purpose using the 1991 Household Travel Survey data, travel impedances obtained from highway and transit networks, 1990 and 2000 U.S. census data, and a variety of other data sources. The mode choice models estimate modal splits for four trip purposes: HBW, Home-based Other (which includes HBPB and HBSR), HBSc, and NHB (which includes NHBW and NHBO). These models have been calibrated and validated. The mode choice models are applied, by purpose, to the intraregional person trip tables that result from the trip distribution model.

The mode choice models split the trips for each purpose among six modes: 1) walk-access transit, 2) drive-access transit, 3) single-occupancy vehicles, 4) high-occupancy vehicles with two or more persons (high-occupancy vehicles with two persons only for the HBW trip purpose), 5) high-occupancy vehicles with three or more persons (for the HBW trip purpose only), and 6) a pure walk mode. The stations used in the execution of drive-access transit trips are identified using a special component of the mode choice model: a station choice model. Specific sub-mode selection (i.e., local bus, express bus, light rail, commuter rail, rapid transit, bus rapid transit, and boat) occurs during the transit assignment process.

The mode choice models estimate mode splits for intraregional trips only (trips contained within the Eastern Massachusetts Region boundaries). They estimate mode shares for both inter-zonal trips (from one zone to another zone) and intra-zonal trips (from and to the same zone); however, intra-zonal trips are only split between the walk and auto modes.

Factors based upon the 1991 household travel survey are used to divide the trip tables produced by the trip distribution models into two trip tables: one for the trips made from production TAZ to attraction TAZ, the other for the trips made from attraction TAZ to production TAZ. The mode choice models are applied to these trip tables in two stages: first for the trips made from production TAZ to attraction TAZ (using the origin-destination input matrices), then for the trips made from attraction TAZ to production TAZ (using the inverse of the origin-destination input matrices).

Variables

The following are brief descriptions of the variables the mode choice models use to estimate mode splits:

Nest coefficient: Represents the degree of interactivity between the modes within the nest and other modes or nests. The value ranges between 0 and 1, with 1 indicating that switches to and from other modes are as likely as switches to and from modes within a nest. A value of 0 indicates there would be no switching between the nest modes and other modes.

In-vehicle travel time (IVTT): Represents time spent in the modal vehicle during a given trip.

Out-of-vehicle time: Includes all walking, boarding, and waiting time.

Drive-access time: Represents driving time between a trip end and a transit station parking lot.

Terminal time: Represents the time it takes to travel between a vehicle and the ultimate trip origin or destination.

Fare: Represents the average transit fare, in dollars, a transit rider will pay to use the system. This is calculated on a modal basis by dividing the total revenue by ridership; this accounts for differences in "discounted" fare media used throughout the system and in the study area. Also included along with this average fare is one-half of any applicable parking costs (one-half because such costs are calculated on the basis of a one-way trip) at a transit station parking facility.

Auto cost: Represents auto operating and toll costs. Also included is one-half of any applicable non-transit parking costs (one-half because such costs are calculated on the basis of a one-way trip) on the street or in a parking facility. Also, for shared-ride modes, total auto costs are divided by the appropriate auto occupancy.

Household size: Represents the average number of persons per household in the production TAZ. This estimate is obtained from the trip generation model.

Vehicles/person: Represents the average number of vehicles per person in a household in the production TAZ. Vehicles are estimated using the vehicle availability model described earlier.

Population density: Represents total population per acre of dry land in the TAZ.

Percent SOV origins/destinations: Represents the AM peak period single-occupant vehicle share of work trip ends within a TAZ, as computed by the home-based-work mode-choice model.

The Four Trip Purposes and the Station Choice Model

Home-Based Work Model

Home-based work (HBW) is the only trip purpose for which the mode choice models distinguish between two-person carpools (HOV2) and three-or-more-person carpools (HOV3+). The model specifications are shown in Table 10.

A transit nest is incorporated into the model on the basis that the decision to take transit over the other modes is made before selection of a particular transit mode. The transit coefficients are the same for both walk access (WAT) and drive access (DAT) transit and include coefficients for in-vehicle, initial wait, transfer wait, and total walk time. Drive-access time and production terminal times are included in DAT as one parameter.

The WAT fare includes the transit fare in dollars. For DAT, costs include the average transit fare and half of any parking cost. Population density by traffic zone, in people per acre, is included in walk-access transit, and it is positively correlated: the greater the density, the more likely a traveler is to choose this mode. The zones with high population densities also have more transit stops. Vehicles per worker is a socioeconomic input unique to this trip purpose for DAT. It is also positively correlated, since a higher vehicles-per-worker ratio increases the likelihood of a vehicle's being available for a trip to a park-and-ride lot.

The auto times and cost coefficients are the same for the three auto modes. For HOV2 and HOV3+ the auto cost is divided by the average vehicle occupancies to reflect the sharing of costs between vehicle occupants. Household size is included as a positively correlated variable for the shared-ride modes and has a somewhat greater impact for HOV3+ than HOV2.

Home-Based Other Model

The home-based other (HBO) mode choice model combines the home-based shopping and home-based recreational trip tables output from the trip distribution process into a single HBO trip table. The model specifications are shown in Table 11. The model is similar to the HBW mode choice model, except for the following three differences. First, since there is only one shared-ride mode, HOV2+, household size is only a parameter for this one mode. Second, the vehicles per person in a household is used, as opposed to vehicles per worker. Finally, a distance dummy equal to one if the trip distance is less than a mile and zero otherwise is added to the walk mode. This reflects the fact that people taking short trips for this purpose are more likely to walk than choose another mode.

Non-Home-Based Model

The non-home-based (NHB) model splits work trips and non-work trips. The model specifications are shown in Table 12. There is a work dummy variable in the two auto modes which is equal to one if the trip is a non-home-based work trip and zero otherwise. The coefficient is positive for SOV and negative for HOV, indicating that the SOV mode is more likely on work-related trips than on non-work trips. The percentage of trips attracted to the origin and destination zones that is SOV is a variable in the drive-alone mode. The percentage is taken from the results of the AM peak period HBW mode choice model and is positively correlated. Finally, the distance dummy in the walk mode is equal to one if the distance is less than a mile. It has a positive coefficient.

Home-Based School Model

The home-based school (HBSC) model was re-estimated and restructured in 2004 to allow for compatibility of the HBSC purpose with the Federal Transit Administration's Summit program. The previous HBSC model had one nest comprising all motorized modes. The revised HBSC model has two nests, transit and highway. The revised HBSC model specifications are shown in Table 13.

Station Choice Model

The final part of the mode choice model is the assignment of drive-access transit trips to transit stations in the station choice model. This model uses estimates of highway travel times and costs from the highway assignment model, estimates of transit impedances from the walk-access transit assignment model, and estimated transit parking lot capacities to distribute drive-access transit trips among the transit stations with parking lots. The model also estimates the impedances associated with the drive-access transit trips between each TAZ pair and, if parking at the transit parking lots is constrained, reassigns demand for full parking lots to other parking lots or to other modes of transportation.

The probability of selecting a station is determined by the combination of utilities for the auto and transit legs of the drive-access transit trip. The utility of the auto leg (U_{ik}) is a combination of the auto travel time between production TAZ i and transit station k (ATT_{ik}) and the parking capacity at transit station k (PC_k).

$$U_{ik} = -.125\ ATT_{ik} + .00025\ PC_k$$

The utility of the transit leg (U_{kj}) is a function of the composite impedance used in transit path selection, which includes transit in-vehicle travel time (ITT_{kj}), boarding time (BT_{kj}), waiting time (WtT_{kj}), fare (F_{kj}), and walk time (WkT_{kj}) accumulated between station k and attraction TAZ j.

$$U_{kj} = -.05 * (ITT_{kj} + BT_{kj} + F_{kj} + (2 * (WtT_{kj} + WkT_{kj})))$$

The auto leg utilities are used to identify the five most likely stations to be used for each production TAZ, the combined utilities are used to estimate the probabilities of selecting each of those stations for each pair of TAZs, and the trips are assigned to transit stations. If transit parking is constrained to capacity, some trips may not be possible since the parking demand exceeds the capacity at the station, so, for those trips, the auto leg utilities are re-estimated to identify the five most likely stations with available parking capacity, and the trips are assigned to transit stations based upon the combined utilities. Trips which are still not assignable due to inadequate parking capacity are then switched to the walk-access transit, single-occupancy vehicle, or high-occupancy vehicle mode in the same proportion of other trips of the same purpose between the same pair of TAZs.

TABLE 10
Home-Based-Work Mode Choice Model Specifications

	Nest Coeff	Impedance Variable: IVTT	Terminal Time	Walk Time	Initial Wait	Transfer Wait	Auto Access	Boarding Time	Fare ($)	Auto Cost ($)	Socioeconomic Variable: Population Density	Vehicles/ Worker	HH Size
Drive-Alone													
Top Level	1	-0.05466	-0.292							-0.32			
Application Level		-0.05466	-0.292							-0.32			
Ratio to IVTT ($/hr)		1	5.34211							$ 10.25			
HOV2													
Top Level	1	-0.05466	-0.292							-0.32			0.07322
Application Level		-0.05466	-0.292							-0.32			0.07322
Ratio to IVTT ($/hr)		1	5.34211							$ 10.25			-1.33955
HOV3+													
Top Level	1	-0.05466	-0.292							-0.32			0.2168
Application Level		-0.05466	-0.292							-0.32			0.2168
Ratio to IVTT ($/hr)		1	5.34211							$ 10.25			-3.96634
Walk													
Top Level	1			-0.1007									
Application Level				-0.1007									
Ratio to IVTT ($/hr)													
Walk-Access Transit													
Top Level	0.6791	-0.05466		-0.1007	-0.11292	-0.11292		-0.05466	-0.32		0.01889		
Application Level		-0.08049		-0.14828	-0.16628	-0.16628		-0.08049	-0.47121		0.02781		
Ratio to IVTT ($/hr)		1		1.8423	2.06593	2.06593		1	$ 10.25		-0.34551		
Drive-Access Transit													
Top Level	0.6791	-0.05466	-0.292	-0.1007	-0.11292	-0.11292	-0.13665	-0.05466	-0.32	-0.32		0.2897	
Application Level		-0.08049	-0.42998	-0.14828	-0.16628	-0.16628	-0.20122	-0.08049	-0.47121	-0.47121		0.4266	
Ratio to IVTT ($/hr)		1	5.34211	1.8423	2.06593	2.06593	2.5	1	$ 10.25	$ 10.25		-5.30011	

TABLE 11
Home-Based-Other Mode Choice Model Specifications

		Impedance Variable									Socioeconomic Variable			
	Nest Coeff	IVTT	Terminal Time	Walk Time	Initial Wait	Transfer Wait	Auto Access	Boarding Time	Fare ($)	Auto Cost ($)	Population Density	Vehicles/ Worker	HH Size	Distance Dummy
Drive-Alone														
Top Level	1	-0.01965	-0.2308							-0.22378				
Application Level		-0.01965	-0.2308							-0.22378				
Ratio to IVTT ($/hr)		1	11.7463							$ 5.27				
HOV2+														
Top Level	1	-0.01965	-0.2308							-0.22378			0.1976	
Application Level		-0.01965	-0.2308							-0.22378			0.1976	
Ratio to IVTT ($/hr)		1	11.7463							$ 5.27			-10.0566	
Walk														
Top Level	1			-0.05895										0.9005
Application Level				-0.05895										0.9005
Ratio to IVTT ($/hr)														-15.2757
Walk-Access Transit														
Top Level	0.3722	-0.01965		-0.05895	-0.05895	-0.05895		-0.01965	-0.22378		0.00883			
Application Level		-0.05279		-0.15838	-0.15838	-0.15838		-0.05279	-0.60123		0.02373			
Ratio to IVTT ($/hr)		1		3.0002	3.0002	3.0002		1	$ 5.27		-0.44951			
Drive-Access Transit														
Top Level	0.3722	-0.01965	-0.2308	-0.05895	-0.05895	-0.05895	-0.04912	-0.01965	-0.22378	-0.22378		0.71239		
Application Level		-0.05279	-0.6201	-0.15838	-0.15838	-0.15838	-0.13198	-0.05279	-0.60123	-0.60123		1.914		
Ratio to IVTT ($/hr)		1	11.7463	3.0002	3.0002	3.0002	2.5	1	$ 5.27	$ 5.27		-36.2564		

TABLE 12
Non-Home-Based-Work Mode Choice Model Specifications

		Impedance Variable									Socioeconomic Variable		
	Nest Coefficient	IVTT	Terminal Time	Walk Time	Initial Wait	Transfer Wait	Auto Access	Boarding Time	Fare ($)	Auto Cost ($)	Work Dummy	Distance Dummy	Percent SOV
Drive-Alone													
Top Level	1	-0.03022	-0.3197							-0.1817	0.1926		0.00885
Application Level		-0.03022	-0.3197							-0.1817	0.1926		0.00885
Ratio to IVTT ($/hr)		1	10.5791							$ 9.98	-6.37326		-0.29295
HOV2+													
Top Level	1	-0.03022	-0.3197							-0.1817	-0.7627		
Application Level		-0.03022	-0.3197							-0.1817	-0.7627		
Ratio to IVTT ($/hr)		1	10.5791							$ 9.98	25.2383		
Walk													
Top Level	1			-0.07525								0.493	
Application Level				-0.07525								0.493	
Ratio to IVTT ($/hr)												-6.5515	
Walk-Access Transit													
Top Level	1	-0.03022		-0.07525	-0.08333	-0.08333		-0.03022	-0.1817				
Application Level		-0.03022		-0.07525	-0.08333	-0.08333		-0.03022	-0.1817				
Ratio to IVTT ($/hr)		1		2.49007	2.75745	2.75745		1	$ 9.98				
Drive-Access Transit													
Top Level	1	-0.03022	-0.3197	-0.07525	-0.08333	-0.08333	-0.07555	-0.03022	-0.1817	-0.1817			
Application Level		-0.03022	-0.3197	-0.07525	-0.08333	-0.08333	-0.07555	-0.03022	-0.1817	-0.1817			
Ratio to IVTT ($/hr)		1	10.5791	2.49007	2.75745	2.75745	2.5	1	$ 9.98	$ 9.98			

TABLE 13
Home-Based-School Mode Choice Model Specifications

	Nest Coefficient	Impedance Variable							Population Density
		IVTT	Terminal Time	Walk Time	Wait Time	Drive-Access Time	Fare ($)	Auto Cost ($)	
Drive-Alone									
Top Level	0.5559	-0.0305	-0.0904					-0.1803	
Application Level		-0.0548	-0.1626					-0.3244	
Ratio to IVTT ($/hr)		1.0000	2.9672					$10.14	
HOV2+									
Top Level	0.5559	-0.0305	-0.0904					-0.1803	
Application Level		-0.0548	-0.1626					-0.3244	
Ratio to IVTT ($/hr)		1.0000	2.9672					$10.14	
Walk									
Top Level	1			-0.0791					
Application Level				-0.0791					
Ratio to IVTT ($/hr)									
Walk-Access Transit									
Top Level	0.5559	-0.0305		-0.0791	-0.0791		-0.1803		0.0150
Application Level		-0.0548		-0.1423	-0.1423		-0.3244		0.0270
Ratio to IVTT ($/hr)		1.0000		2.5967	2.5967		$10.14		-0.4927
Drive-Access Transit									
Top Level	0.5559	-0.0305	-0.0904	-0.0791	-0.0791	-0.0762	-0.1803	-0.1803	0.0150
Application Level		-0.0548	-0.1626	-0.1423	-0.1423	-0.1371	-0.3244	-0.3244	0.0270
Ratio to IVTT ($/hr)		1.0000	2.9672	2.5967	2.5967	2.5018	$10.14	$10.14	-0.4927

TRIP ASSIGNMENT

Trip assignment is the fourth step in the travel demand forecasting process and in CTPS's regional travel demand model. Trip assignment is the process by which each trip in the trip tables resulting from the mode choice model is assigned to a specific submode (for example, bus or rapid transit) and a specific route. The CTPS model uses two distinct assignment procedures, one for the transit trips and one covering the highway trips.

Highway Assignment Routine

The highway assignment implemented in EMME is an equilibrium assignment. The fundamental assumptions underlying such an assignment procedure are that each user of the highway network knows all of the network times, costs, and distances and will choose the route that he or she perceives to be the best. The assignment is an aggregate assignment in that traffic volumes on any given link are an aggregate number, as opposed to being associated with a specific trip. There are several inputs used by the EMME equilibrium assignment procedure. The key inputs are the highway demand matrices, the volume delay function, and the highway network:

- Highway demand matrices

  The demand matrices that the highway assignment procedure uses as an input are the demand matrices that result from the mode choice and distribution models and other sources. These are origin-destination matrices of single-occupancy vehicles, trucks, taxis, internal-external/external-internal trips, through trips, and high-occupancy vehicles.

  To prepare the mode choice trip tables for use in highway assignments, it is necessary to convert person trips to vehicle trips by applying vehicle occupancy factors for HOV modes. These occupancy factors, presented below, vary by trip purpose and are based upon the 1991 household travel survey.

Home-based work trips	HOV2:	2 persons/vehicle
	HOV3+:	3.373 persons/vehicle
Home-based other trips	HOV2+:	2.404 persons/vehicle
Home-based school trips	HOV2+:	2.788 persons/vehicle
Non-home-based trips	HOV2+:	2.385 persons/vehicle

  In addition to manipulating the output matrices from mode choice, it is necessary to bring in vehicle trip tables produced outside of the mode choice process. These vehicle trip tables are:

  - External Through – This matrix consists of trips that pass through the study area without stopping and hence are exogenous to the travel model. The trips were estimated from the latest external travel survey, 2010 American Community Survey data, and traffic counts.
  - Taxi – The taxi vehicle trip table was originally developed from a 1993 survey and has since been revised several times based upon a factoring process.
  - Logan Airport SOV and HOV – This trip table is developed from a separate Logan Airport Passenger Mode Choice Model, which was developed based on a 2007 Massachusetts Port Authority survey and validated with a 2010 Massachusetts Port Authority survey.
  - Drive-Access-Transit Auto Access – DAT trips are determined through the station choice model, which is a part of the mode choice process. Each DAT trip requires a vehicle access trip.
  - Interregional SOV and HOV – The interregional vehicle trip tables are generated through the interregional trip distribution model.
  - Pick-Up/Drop-Off SOV and HOV – The pick-up/drop-off (PUDO) tables, produced by the interregional trip distribution model, cover those trips in which a person is dropped off at or picked up from his or her destination (not an intermediate parking lot).
  - Truck – The truck trip tables, which cover commercial truck trips within the region, are produced from the CTPS tour-based truck trip model. Further information about this model is presented later in this memorandum.

- Volume-delay function

  The function used in the highway assignment procedure is a volume-delay function, which, when applied in the context of a highway assignment, changes the speeds users of the network experience based upon the volumes on the network. The volume-delay functions employed in the CTPS regional model are variations on the so-called Bureau of Public Roads (BPR) function. Developed by its now defunct namesake, the BPR function is a widely used and validated volume-delay function that is parabolic in shape and takes the form:

  Congested Speed = (Free-Flow Speed)/(1 + 0.83*$[\text{Volume/Capacity}]^b$)

  The form of this equation used for expressways uses 5.5 as the value of b, the exponent for the volume-capacity ratio. The form of the equation used for all other roadways in the network uses 2.7 as the exponent.

  The CTPS regional model is segmented by time periods. For each time period, the BPR function is altered to reflect the number of hours of vehicle capacity in that period.

- Highway network

  The highway network is an abstract digital representation of the real highway network in eastern Massachusetts. For future-year scenarios, the highway network depicts roadway links that are planned in addition to the existing highway network. The base-year highway network is a depiction of the eastern Massachusetts highway network as it existed in the year 2012. The highway network in the base and future years includes information about number of lanes, free-flow speeds, and capacity (in vehicles per lane per hour). Freeways typically have a free-flow speed of 60 miles per hour, are three lanes, and have a capacity of 1,950 vehicles per lane per hour. Smaller arterials typically have a free-flow speed of 30 to 45 miles per hour, are coded as having one or two lanes, and have a capacity of 900 to 1,000 vehicles per lane per hour. Such parameters are consistent with widely accepted traffic engineering principles and the Transportation Research Board's *Highway Capacity Manual.*

  The highway assignment procedure performs a multi-class generalized cost equilibrium auto assignment. The multi-class assignment runs an assignment for the demand matrices of five modes, SOV, HOV, pickup trucks and vans, hazardous material trucks, and other commercial trucks, from the total vehicle trip tables for each class, which are assigned by time period. Tolls affect the assignment and are stored on the network.

  The highway assignment procedure is iterative in that the assignment is calculated repeatedly, in order to mathematically optimize assignment results. Three criteria are used to determine how many iterations of the assignment procedure are used:

  First, the relative gap is an estimate of the difference between the current assignment and a perfect equilibrium assignment, in which all paths used for a given origin-destination pair would have exactly the same time. The default relative gap is 0.5%, but CTPS employs 0.01% so that a more accurate assignment will result.

Another criterion for when to stop the iterations is the normalized gap (or trip time differential), which is the difference between the mean trip time of the current assignment and the mean minimal trip time. The mean trip time is the average trip time on the paths used in the previous iteration; the mean minimal trip time is the average trip time computed using the shortest paths of the current iteration. Again, a minimum level is selected, 0.01 minutes, in order for the designated number of iterations to be carried out.

If neither of these criteria is met, the CTPS regional model highway assignment procedure is set to stop after running through 50 iterations.

Transit Assignment Routine

The transit assignment used in EMME is a multi-path assignment based on the calculation of optimal transit strategies for system users. A transit strategy is roughly analogous to a path in highway assignment. The transit assignment allows for users of the transit system switching within the transit network between various available transit services in order to reach their destination. In basic terms, the transit assignment algorithm identifies the optimal service or services at each node in the transit network for each origin and destination node pair. This algorithm is repeated for all nodes, starting with the destination node and culminating at the origin node.

Like the highway assignment procedure, the transit assignment procedure utilizes several key inputs to estimate a transit assignment. Three of the key inputs are the transit demand matrices, the transit functions, and the transit network:

- Transit demand matrices

  The transit demand matrices are just that, matrices of trips that have been split into the transit mode because the utility of their trip suggests that transit is the most attractive mode choice for their particular origin-destination pair. These trip tables come from three sources:
    - Walk-access transit trip tables from the mode choice model
    - Drive-access transit trip tables from the station choice model
    - Logan transit trip tables from the Logan Airport Passenger Mode Choice Model

- Functions

  The function used in the transit assignment procedure depicts the relative levels of attractiveness among the numerous paths available in the eastern Massachusetts transit network for each pair of TAZs. Costs are translated to time assuming a value of time of $12 per hour (using 1991 dollars) and doubling the out-of-vehicle time (walking, boarding, and wait times) before adding it to in-vehicle time.

- Transit network

  The transit network is an abstract digital representation of the real transit network in eastern Massachusetts. For future-year scenarios, the transit network depicts transit links that are planned in addition to the existing transit network. The base-year transit network is a depiction of the eastern Massachusetts transit network as it existed in Spring 2012. The transit network includes every commuter rail line, rapid transit line, bus route, bus rapid transit route, and ferry route and many free shuttle routes in eastern Massachusetts. The bus routes run on the highway network, and their run times are influenced by roadway traffic congestion. Among other things, the transit network in the base and future years includes estimated vehicle headways, wait times, transit run times, and fares for each line. The assignment algorithm takes into consideration all of these elements in calculating a transit assignment.

  Additionally, the transit network represents and accounts for park-and-ride facilities. Park-and-ride nodes provide connections between the highway and transit networks via a walk link. As a result, drive-access transit trips use both the highway and the transit networks.

  The transit network also includes an extensive set of walk-access and transfer links. All these links assume a walk speed of 3 miles per hour.

  Walk-access links are an abstract representation of all of the walking routes transit users utilize in eastern Massachusetts to access the transit system. In other words, they are an aggregate abstraction of the sidewalks, roadways, backyards, driveways, and shortcuts people use to walk to the transit system.

  The walk-access estimation process is an automated process that involves three steps. The first step builds paths and distances on a walk network roadway geographic information system (GIS) coverage that is created from the most recent statewide digital line graph (DLG) coverage of the roadway network. The roadways that are unsuitable for walking within the study area are then cut from that coverage. The path building and distance skimming between transit stops and zones is calculated on this coverage. The distances between the transit stops and stations active under the scenario under study and each TAZ are then calculated from this coverage. Up to two walk links are created between each TAZ and the stations and stops on each transit line, with no links over one mile. Transfer links are created to connect all stations and stops within a quarter-mile walk of each other.

Fare Coding

Average fares are used for coding in the EMME network. Each transit submode (boat, bus rapid transit, rapid transit, bus, commuter rail, and shuttle) is assigned a boarding fare that is placed on the walk access and transfer links serving the nodes that serve the stations and stops for that submode. Additional zone fares are represented as segment fares placed on the transit links crossing the fare zone boundaries. In addition, park-and-ride parking charges are coded onto the walk links that connect the park-and-ride nodes to the transit station and stop nodes.

Fares are translated into time for influencing path selection by assuming a value of time of $12 (in 1991 dollars) per hour. Although fares are expressed in minutes to allow them to be included in the impedances that influence path selection, they are kept separate from travel times for input into the mode choice model.

ADDITIONAL PRE-ASSIGNMENT MODEL COMPONENTS

TRUCK TRIP MODEL

An integrated behavioral tour-based model was developed from CTPS's Vehicle Inventory and Use Survey, Massachusetts Registry of Motor Vehicle files, and existing truck trip generation rates. These existing sources were supplemented by specifically-focused telephone and travel-intercept surveys and video data capture which provided information used to quantify key behavioral relationships.

The truck travel forecasting model incorporates several new factors into the truck trip tables used for highway assignments. With these changes, the truck model produces truck travel estimates which are sensitive to demographic changes and which are consistent with the roadway network and observed truck travel patterns and operating characteristics. These innovative features can be characterized into three major elements:

- **BEHAVIORAL.** The model is based upon functional usage categories which capture relatively homogeneous patterns of truck operation and are tied to regional socioeconomic characteristics.

- **TOUR-BASED.** The model differentiates between truck trip tour ends and their intermediate starts and stops in order to impose a tour-like form on the pairing of truck trip ends. This, as a result, distributes truck trip ends appropriately between truck garage sites and truck starts and stops along delivery routes.

- **INTEGRATED.** The model is sensitive to changes in a specific set of interacting variables that are internally consistent and externally constrained. The variables include sector employment and population, truck ownership and operational characteristics, highway network truck restrictions, link truck volume counts, time-of-day, and intra-regional and inter-regional truck travel demand. Truck travel volumes are estimated as a function of the population and employment by type of business in each TAZ.

The underlying premise of the modeling approach is that overall truck travel demand can be divided into nine relatively identifiable and homogenous functional usage categories. Each of the nine is comprised of relatively similar travel characteristics as measured in such variables as tours per day, trips per tour, and trip length.

These nine distinct categories are:

- Tankers – distinct body type, many carry hazardous materials.
- Household Goods - perform distinct service, as they move the belongings (not products) of their clients
- Less-than-truckload/Truckload – commercial carriers transporting wide varieties of goods
- Food and Warehouse Distribution – distributing goods (sometimes non-durable, so time-sensitive) to retail outlets.
- Intermodal – picking up or delivering goods also carried by rail or boat.
- Package – distinct service type, many stops per tour.
- Heavy – large vehicles, most subject to weight limitations.
- Retail – delivering goods to end users.
- Pickup/Van – small vehicles, least subject to restrictions.

Within the modeling process, a series of relationships were established among firm employment, firm truck ownership/usage, and truck type and usage category. These relationships are expressed in terms of both FHWA physical vehicle classes and usage categories. This correspondence made it possible to validate and, where necessary, to adjust the travel demand matrices through use of trip table estimation techniques. In this way, the initial demand levels for four time periods were adjusted to observed truck volumes from counts conducted on links of the highway system.

LOGAN AIRPORT PASSENGER GROUND ACCESS MODE CHOICE MODEL

The last pre-assignment step in the CTPS Regional Travel Forecasting Model Set is the Logan Airport passenger ground access mode choice model. This model uses estimated times and costs for travel to Logan Airport, characteristics of Logan Airport passengers and their trips, and basic information about Logan Airport travel services to predict the amount and patterns of travel to and from Logan Airport.

The CTPS Logan Airport passenger ground access mode choice model is composed of the following seven parts:

- Estimation of travel times and costs within the region
- Estimation of travel times and costs outside the region
- Estimation of Logan Airport passenger characteristics
- Estimation of Logan Airport passenger trip characteristics
- Estimation of unconstrained passenger access trip mode choice distribution
- Estimation of Logan Airport parking demand
- Estimation of constrained passenger access trip mode choice distribution
- Estimation of passenger egress trip mode choice distribution
- Estimation of passenger vehicle volumes

Estimation of travel times and costs within the region

The Logan Airport passenger ground access mode choice model includes the following modes as options for passenger travel to Logan Airport:

- MBTA Blue Line – walk access and drive access
- MBTA Silver Line – walk access and drive access
- Private bus
- Logan Express – drop-off and parking
- Water shuttle
- MBTA local bus
- Limousine
- Taxi
- Hotel shuttle
- Long-term parking at Logan
- Long-term parking off Logan
- Logan Airport Drop-off
- Short-term parking at Logan
- Rental car

The time and cost for traveling to each of the terminals at Logan Airport is a basic input into the model calculations. The times and costs experienced by Logan Airport passengers are broken down into the following components:

- Wait time
- In-vehicle time
- Walk time
- Auto access time
- Transfer time
- Number of transfers
- Parking fee
- Auto operating cost
  - Highway toll
- Transit fare

Estimates of the times and costs of travel to Logan Airport via each of the modes of travel are obtained for each of the four time periods from the highway and transit networks and assignment models prepared for the Eastern Massachusetts region by the Central Transportation Planning Staff (CTPS). The transit assignment model usually produces one combined set of travel time and cost estimates for all transit services, but this model requires a separate set of travel time and cost estimates for each of the six transit submodes (MBTA Blue Line, MBTA Silver Line, MBTA local bus, Logan Express, and water shuttle). In order to obtain these sets of travel time estimates, a special Logan access link is added to the transit network for each of the transit submodes. Times and costs for each of the submodes are then estimated by assigning paths over the network with the five other submodes' special Logan access links removed from the network and generating time and cost estimates from the paths connecting each TAZ to Logan.

These travel time and cost estimates apply to use of transit with walk access. These walk-access impedance estimates are combined with highway travel time and cost estimates from the CTPS regional highway network and assignment model to produce estimates of the times and costs of transit to Logan with drive access.

In addition to the network-generated travel time and cost estimates, vehicular travel times on Logan Airport and walking times on Logan Airport were provided by Massport in 2008.

Estimation of travel times and costs outside the region

A significant portion of the passengers using Logan Airport come from outside of the Eastern Massachusetts region covered by the CTPS regional model. Since passengers make their choices about travel to Logan based upon the whole access trip, not just the component within the region, estimates of the times and costs of travel to Logan from points outside the region are needed for the model to cover all passengers. These estimates were generated for each city or town identified as origins for ground access trips to Logan in the 2010 Logan Airport Passenger Survey. Times and costs for transit travel from outside of the region were estimated from a manual review of train and bus schedules and the manual selection of most likely paths from each city or town. In addition, a manual review of the roads outside of the region led to identifying the most likely path to the airport from each city and town and an estimate of the time and cost of the travel to the external station on the regional boundary. Those external highway times and costs were then added to the times and costs of travel from the external station to the transit station (for drive access modes) or Logan.

Estimation of Logan Airport passenger characteristics

Characteristics of the passengers traveling to Logan which were found to effect mode choice include the following:

- Number of flights from Logan per year
- Location of residence
- Household income
- Number of people in household
- Household auto ownership

This information was obtained for each passenger from the 2010 Logan passenger survey.

Estimation of Logan Airport trip characteristics

Characteristics of the access trip to Logan and the trip being taken by plane which were found to effect mode choice include the following:

- Purpose of travel (business or non-business)
- Payment of travel costs (employer or self)
- Trip origin location

- Trip origin type
- Number of days
- Size of travel party
- Number of pieces of luggage

This information was obtained for each passenger from the 2010 Logan passenger survey.

Estimation of unconstrained passenger access trip mode choice distribution

The Logan Airport passenger ground access mode choice model used to forecast the distribution of Logan Airport passengers by mode of access is of the disaggregate multinomial logit form. This form assumes the probability of a passenger selecting a mode i (P_i) is equal to the ratio of the exponentiated utility (attractiveness) of that mode for that passenger's trip to Logan (U_i) to the sum of the exponentiated utilities for all modes for that passenger's trip to Logan. This can be expressed as:

$$P_i = \frac{e^{U_i}}{\sum_i e^{U_i}}$$

The model actually is made up of a set of models – one for each of the four distinct segments of the passenger market. Since residents of the area are more familiar with the options for travel to the airport and have more options available to them than non-residents do, resident and non-resident passengers form separate segments of the passenger market. In addition, business travelers tend to be more time-sensitive and less cost-sensitive in their mode selections than non-business passengers are, so business and non-business passengers also divide the passenger market. As a result, a separate model is prepared for each of the following market segments:

- Resident Business Passengers
- Resident Non-Business Passengers
- Non-resident Business Passengers
- Non-resident Non-business Passengers

Each of these models consists of a series of equations (see Exhibits 1 – 4) quantifying the utility the passengers would experience if taking each of the possible modes for their trip to Logan Airport as a function or the variables discussed above. When applied to the 2010 survey records and the travel times and costs generated by external manual path selections and the 2010 CTPS highway and transit networks, these equations yield the same distribution of Logan Airport passengers by ground access mode as reported in the 2010 Logan Airport passenger survey.

Forecasts of Logan Airport passenger travel patterns are then made by attaching the 2010 Logan passenger survey records to the travel time and cost estimates associated with the TAZ, town, or city of their trip origin. The utility equations are then applied to these combined records to identify the probabilities of taking each of the possible modes. The probabilities estimated for each record are multiplied by the number of passengers the record represents (the survey expansion factor in the base year, but adjusted to match the desired total number of passengers) to yield the estimated distribution of passengers by mode.

Modes unavailable to the type of passenger represented in each segment of the passenger market are not included as alternatives in the model. As a result, residents are not able to use a rental car to Logan, while non-residents are not given the option of parking long-term at Logan, economy at Logan, remotely, or at Logan Express.

Different sets of modes that are similar and are apparently grouped in a joint decision process are joined in nests to reflect this in forecasting Logan mode choices. As a result, resident business passengers first choose whether or not to park long-term at or near Logan before choosing whether to park on Logan or remotely. Similarly, resident non-business passengers are assumed to select among the walk-access transit, door-to-door service, long-term parking, drive-access transit drop-off, Logan drop-off, or Logan Express parking options before deciding among the submodes within those nests.

The non-resident business passenger model indicates the choice of whether to rent a car comes before deciding between the various other modes and these passengers choose between a door-to-door service and the other non-rental modes before selecting among the door-to-door services. Finally, non-resident non-business passengers decide whether to use a rental mode (Logan or off-Logan), door-to-door service (taxi, limousine, or shuttle) or walk-access transit (MBTA Blue Line, MBTA Silver Line, MBTA local bus, or Water Shuttle) to Logan before choosing which of those sub-options is preferable.

Estimation of Logan Airport parking demand

One of the major constraints on passenger choice of mode of access to Logan Airport is the availability of parking at the airport. As a result, the Logan Airport passenger ground access mode choice model must include an estimate of the demand for parking at Logan.

This was done by estimating a model of Logan Airport parking demand. First, the numbers of passengers identified as selecting the long-term parking on Logan Airport, economy parking, and short-term parking modes were translated into numbers of vehicles through dividing the number of passengers each record represents by the number of people in the traveling party. The long-term parking demand is then calculated by adding the vehicles using the long-term and economy parking modes to the number of vehicles parked each day the vehicle would be parked at Logan (for example, Monday, Tuesday, and Wednesday if the survey record was for a two-day trip starting on a Monday).

Finally, the short-term parking demand is calculated by adding a portion of the vehicles using the short-term parking mode to the number of vehicles parked on the day the vehicle would be parked at Logan. Using linear regression to find the best match of model results to Logan Airport parking data from the period of the 2010 survey, assuming the share of the day taken up by each short-term parking vehicle was 0.5, the daily adjustments to the parking totals are estimated as 1.23 for Monday, 1.04 for Tuesday, .95 for Wednesday, .78 for Thursday, .73 for Friday, .994 for Saturday, and 1.21 for Sunday.

Estimation of constrained passenger access trip mode choice distribution

Since the future demands for parking are expected to exceed available supplies, the model was set up to reflect the impacts of constrained parking capacities upon future travel patterns.

These capacity constraints are implemented by taking a weighted average of multiple runs of the model set, with the result of the unconstrained model (reflecting Logan passenger behavior in 1993) combined with the results of model runs where all Logan parking modes are unavailable. For example, if the Logan area parking demand exceeds available supply by 5%, the forecast travel patterns will be a combination of 95% of the results of the unconstrained model run and 5% of the results of the model run with no parking available in the Logan area.

Estimation of passenger egress trip mode choice distribution

Logan passengers also use transit modes and the highways for traveling from Logan Airport to their egress trip destination. The egress trip volumes are not necessarily just the inverse of the average weekday access trip volumes calculated in this model. This is due to several factors:

- Many weekday access trips are matched to weekend day egress trips
- Many weekday egress trips are matched to weekend day access trips
- Many egress trips are made at times when the mode used for access is not available
- Many access trips are made at times when the mode used for egress is not available

The distribution of Logan passenger egress trips by mode is thus estimated. The 1993 Logan passenger survey also asked passengers for their mode of egress from Logan. A cross-classification of access mode by egress mode for each of four time periods (weekday AM peak, midday, PM peak, and night time) was prepared from the survey. These cross-classification factors were then applied to the estimated distributions of passengers by access mode for each time period to estimate the distribution of passengers by egress mode for each time period.

Assumptions used in this application included the following:

- Those passengers using a long-time parking mode or the Logan Express parking mode for access would also egress by that mode
- The destination TAZ for the egress trip from Logan Airport is the same as the origin TAZ for the access trip to Logan Airport except when the following applies
- Egress trips using a walk access transit mode are restricted to destination TAZs with walk access to the transit mode

Estimation of passenger and vehicle volumes

The results of the Logan Airport passenger ground access mode choice model are to be assigned in the CTPS regional transit and highway assignment models. The following trip tables are thus created for each of the four weekday time periods:

- MBTA Blue Line passenger trips
- MBTA Silver Line passenger trips
- MBTA local bus passenger trips
- Private bus passenger trips
- Logan Express drop-off passenger trips
- Logan Express parking passenger trips
- Water shuttle passenger trips
- Highway vehicle SOV trips
- Highway vehicle HOV trips