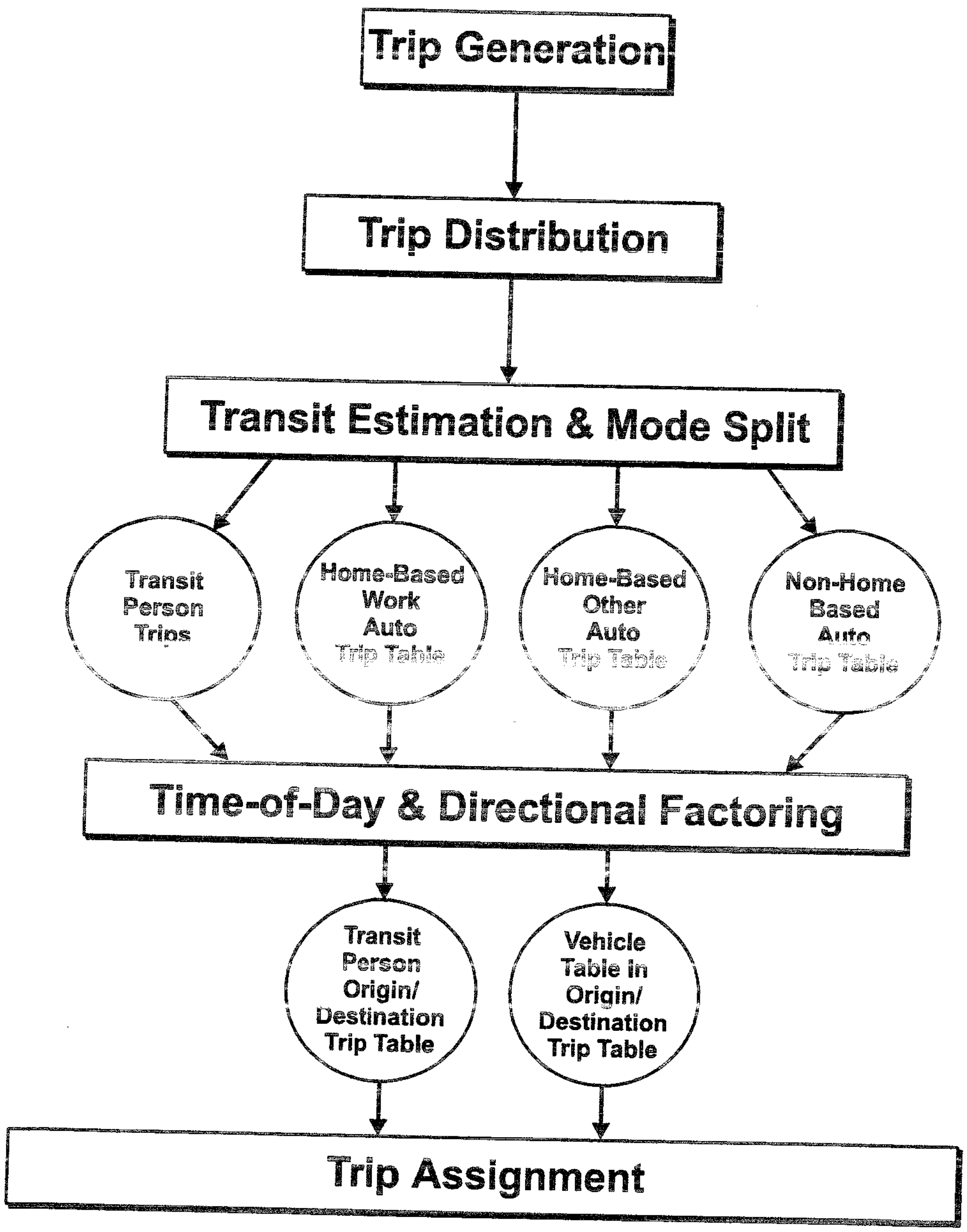
Session 9: Time-of-Day and Directional Factoring



Session 9: Time-of-Day and Directional Factoring

Objectives:

- Discuss need for time-of-day modeling
- Identify trip purpose characteristics that change by time-of-day
- Explain differences between Ps&As and Os&Ds

Session 9: Time-of-Day and Directional Factoring

Session Outline

- Terminology
- Background
- Key concepts
- Inputs and outputs
- Data collection
- Data analysis
- Forecasting future year factors
- Example factors

Session 9: Time-of-Day and Directional Factoring

SESSION OUTLINE

This session discusses the terminology involved in time-of-day directional factoring, background information, and key concepts involved in the process. The session also presents inputs and outputs, data collection techniques, data analysis techniques, and information on forecasting future year factors. The session concludes with an example of the factors used on the Houston/Galveston travel model.

In the past, travel models were used to estimate demand for average 24-hour weekday school year travel. Today, travel models are used to estimate demand for different time periods within the day. Travel demand models are used as analysis tools for a broad range of issues on transportation policy and project alternatives. These issues require analysis spatially and temporally. As an example, the FHWA and EPA conformity rule requires that emissions estimates be based on both peak and off-peak speeds in serious, severe, and extreme ozone nonattainment areas with a population over 200,000.

Notes:

Terminology

- Peak - (4:00 p.m. to 6:00 p.m.)
- Peak hour - (4:45 p.m. to 5:45 p.m.)
- Proportion in peak (K) - (urban freeway - 0.09 - 0.10, suburban freeway- 0.10 - 0.15, rural freeway - 0.15 - 0.20)
- Peak spreading
- Auto occupancy by trip purpose

Terminology

Peaks are typically revealed by a graph of trips by time of day. However, whether categorized by purpose or by geographic area, trips occur at different rates at different times of day. These peaks play a key role in conventional travel demand analysis, which focuses on maximum infrastructure needs in each corridor. The dominant weekday peaks are in the morning (AM peak) and the late afternoon (PM peak), obviously related to the timing of work trips. A peak can be characterized by its maximum trip rate (in trips per unit time) or by duration over which some threshold trip rate is maintained. The portions of the peak before and after the peak are called the "shoulders" of the peak.

Peak hour is the hour during which the maximum traffic occurs. The peak hour during which traffic is highest varies from link to link and place to place, a fact which is not fully reflected in traditional travel demand analysis.

Proportion in peak (k) is the ratio of peak hour volume to 24-hour volume for a given location.

Peak spreading is the lengthening of the peak period, usually accompanied by a flattening of the peak.

Auto occupancy by trip purpose is the average number of persons in an automobile computed by trip purpose from travel survey data.

Notes:

Background

Historically, models were used for:

- Urban transportation planning
- Traffic volume forecasts for geometric design
- Traffic volume forecasts for pavement design

Now additionally used for:

- Evaluating policy alternatives
- Evaluating project alternatives
- Evaluating transportation demand management (TDM) programs
- Evaluating transportation system management (TSM) programs
- Air quality analysis

Background

Historically, travel models were used primarily to:

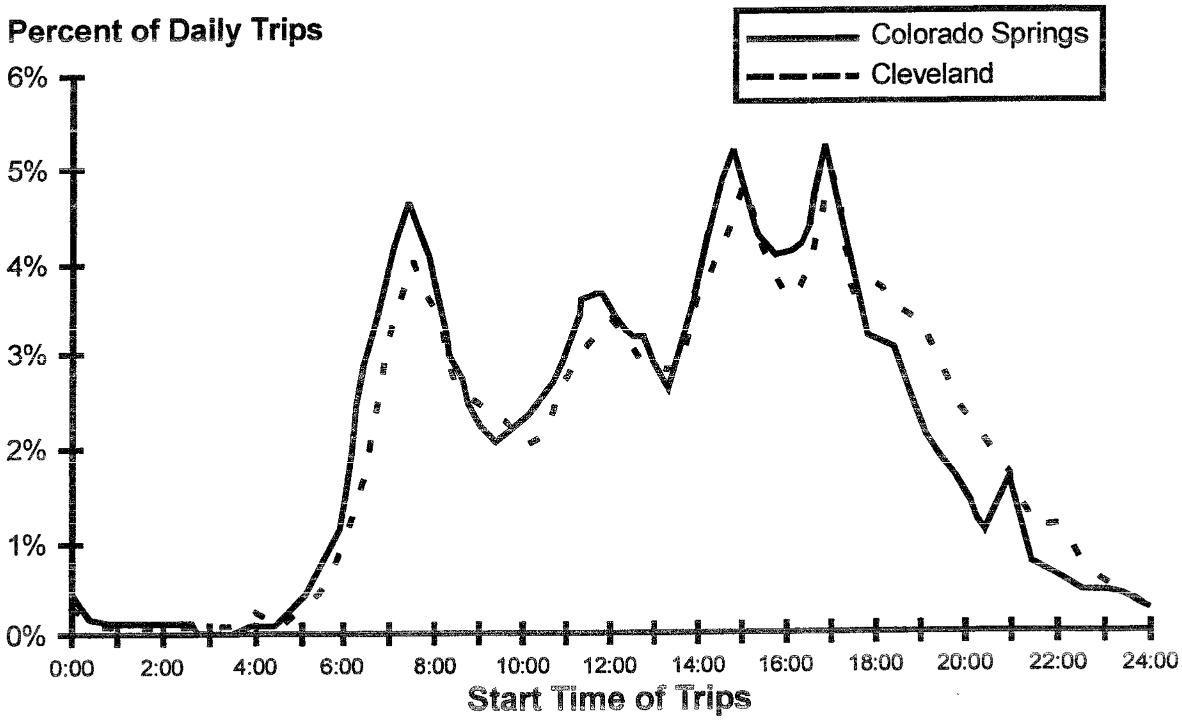
- Support urban transportation system planning (determining location, size, and capacity of major transportation facilities, including freeway and arterial highway systems and transit lines).
- Provide traffic volume forecasts for project level geometric design.
- Provide traffic volume forecasts for project level pavement design.

Increasingly, travel models are now used for:

- Evaluation of transportation policy alternatives (such as congestion pricing, and parking supply and cost policies).
- Evaluation of transportation project alternatives.
- Evaluation of transportation demand management (TDM) programs.
- Evaluation of transportation systems management (TSM) programs.
- Support of transportation air quality analyses (mobile source emission inventories, MTP conformity analyses, congestion management air quality [CMAQ] project analyses, and TCM project and program analyses).
- These later applications need travel models that are spatially and temporally sensitive. Planners need to know how projects and programs will impact congestion by location and by time of day.

Notes:

Key Concepts



Key Concepts

Travel varies by time of day in patterns that are consistently repeated in all major urban areas. The figure shows the percent of daily trips by the trip start time for Colorado Springs and for Cleveland. The distribution of trip starts by time of day is nearly identical for these two urban areas. Notice the characteristic morning peak, a more modest midday peak, and a higher afternoon peak. The afternoon peak is higher because persons do more trip chaining on their trips home from work than they do on their trips to work. In addition to a stop at the day care center, trips to the grocery or other retail stores are frequently made because many of these establishments are not open in the morning peak.

In the past, travel modelers have observed time-of-day patterns for the base year conditions and assumed that the observed patterns will persist in the future. Such simplistic assumptions may no longer be adequate for large urban areas with significant traffic congestion. Observed data indicate that as the amount of travel and congestion in the peak period increases, peak spreading is observed.

Notes:

Key Concepts

Reasons for using time-of-day modeling:

- Vehicle emissions and air quality analyses
- Congestion management programs
- Transit analysis
- Transportation demand management
- Time-of-day travel choices

Key Concepts

There are several reasons why an urban area may choose to use time-of-day modeling procedures. Time-of-day travel modeling is needed to support transportation planning and engineering applications in several areas. Among these are the following:

- **Vehicle emissions and air quality analyses.** The Clean Air Act Amendment (CAAA) of 1990 established stringent air quality standards. CAAA implementing regulations have established analysis procedures for mobile source emissions that require forecasted traffic volumes; vehicle speeds; traffic composition; and vehicle miles and hours of travel by facility type, and by hour of the day. Emerging mobile source emission rate models may require even finer characterization of vehicle activity.

- **Congestion management programs.** ISTEA, TEA-21, and state congestion management programs have established stringent analytical standards. Travel models are needed to forecast the travel speed, congestion delay, and shifts in time-of-day travel that would result from congestion management programs.

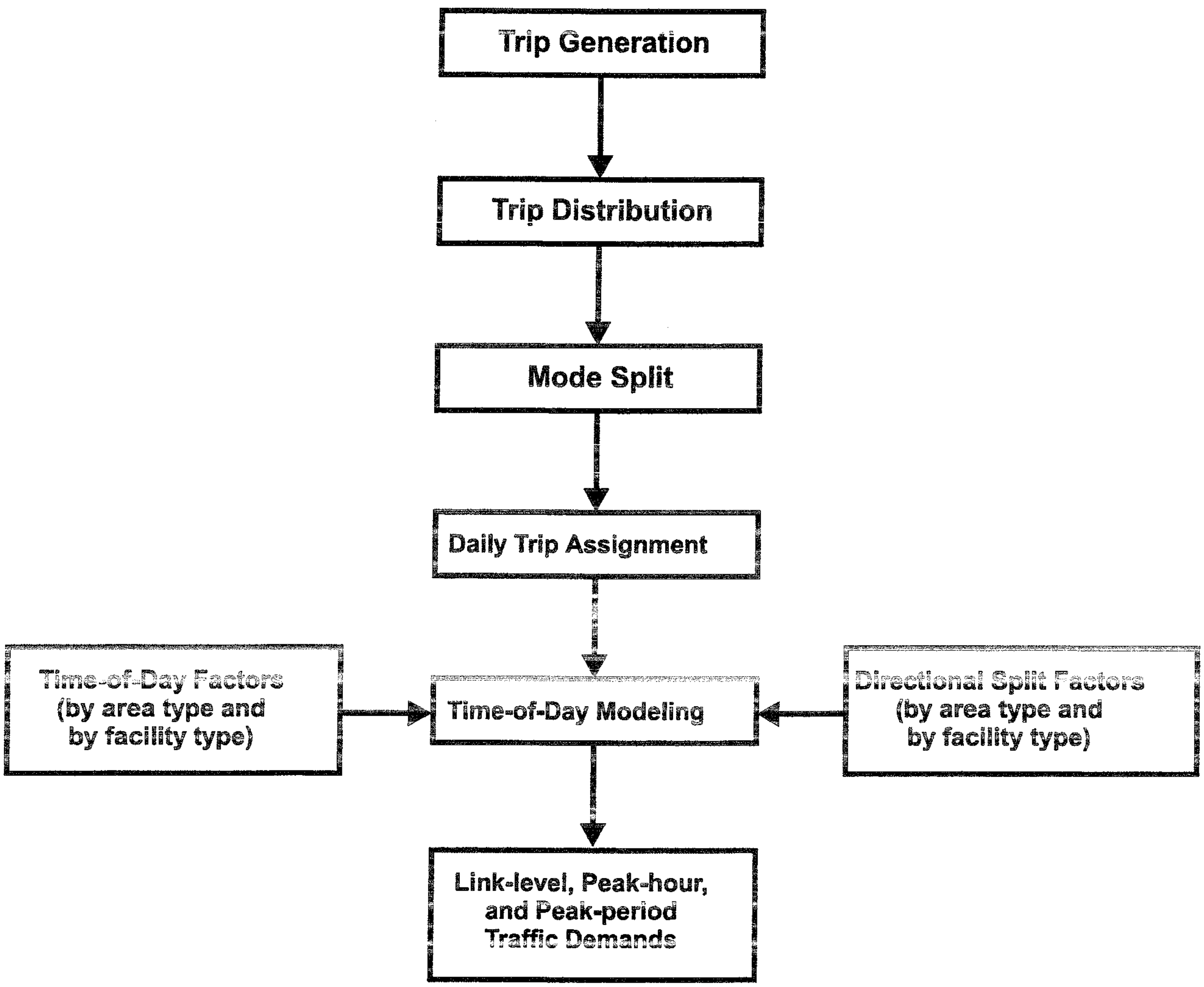
- **Transit analysis.** Historically, transit mode choice models have forecasted daily travel and have used all-or-nothing assignments. This practice limits capability of travel models to forecast transit patronage for different alternatives and to forecast where patronage is sensitive to base and peak period transit supply.

- **Transportation demand management.** TDM programs primarily are aimed at reducing peak period congestion through the reduction in the number of auto trips using programs such as parking charges, congestion pricing, transit subsides, variable work hours, and telecommuting.

- **Time-of-day travel choices.** For some trip purposes, people have some choice as to when the trip is made. This choice is evidenced by peak spreading. As congestion increases, it is expected that more travelers will move departure times away from peak periods.

Notes:

Time-of-Day Modeling after Trip Assignment



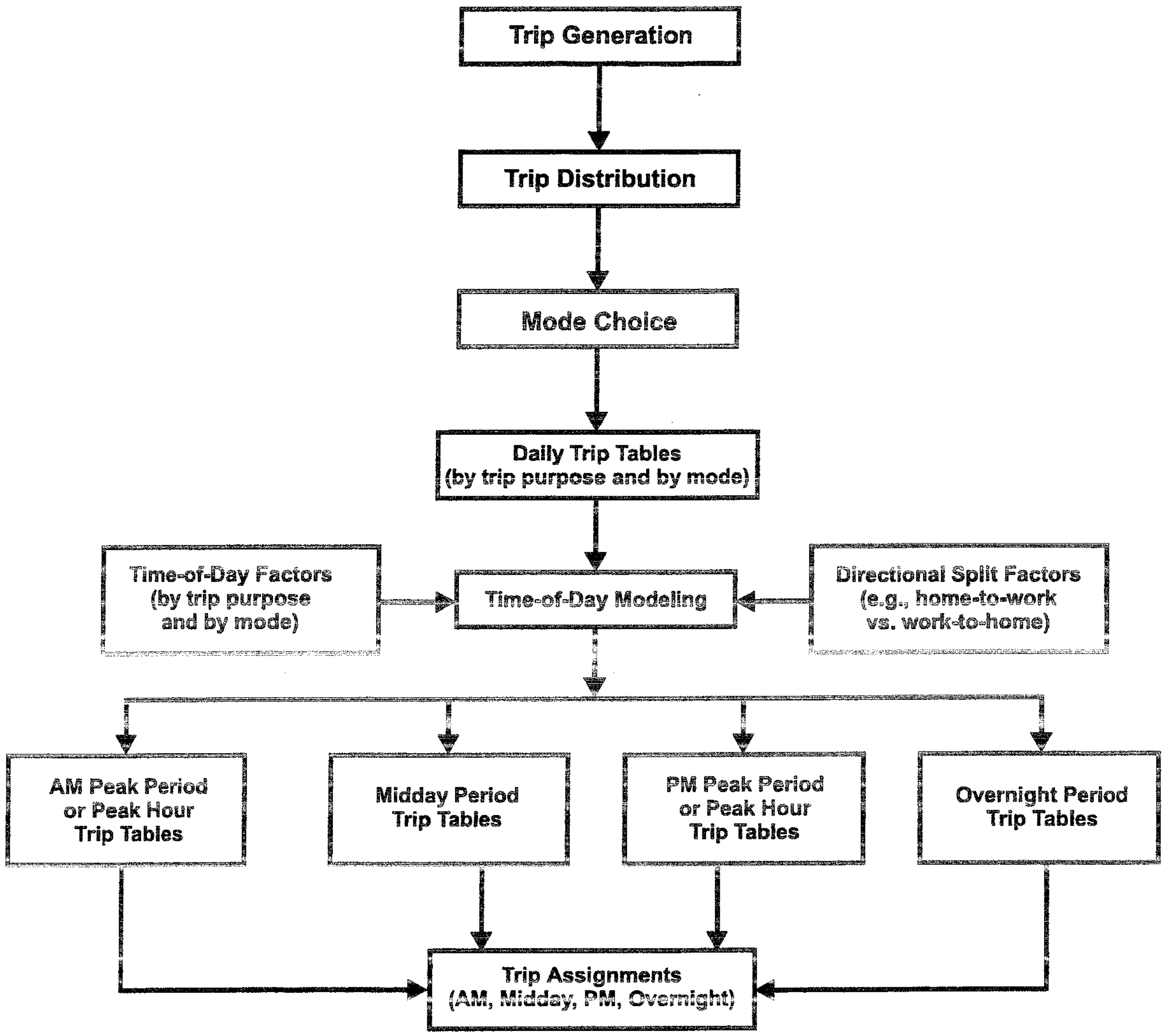
Time-of-Day Modeling after Trip Assignment

There are two approaches typically used for time-of-day modeling. The first approach is time-of-day modeling after trip assignment, which is the simplest and most commonly used approach. It is a post-assignment technique. The required peak period factors used to estimate peak period travel demand are obtained from observed traffic.

The daily (24-hour) link volumes are multiplied by the peak period factor to estimate peak period travel demand. The directional split percentages derived from observed traffic are applied to the link-level peak volumes. A simplifying assumption that peak period factors and directional split factors are uniform for the urban area, is sometimes needed. Preferably, the model uses peak period factors and directional split factors that vary by area type (CBD, urban, suburban, and rural) and functional classification (freeway, principal arterial, and collector). This method of time-of-day modeling after trip assignment is summarized in the figure.

Notes:

Time-of-Day Modeling between Mode Split and Trip Assignment



Time-of-Day Modeling between Mode Split and Trip Assignment

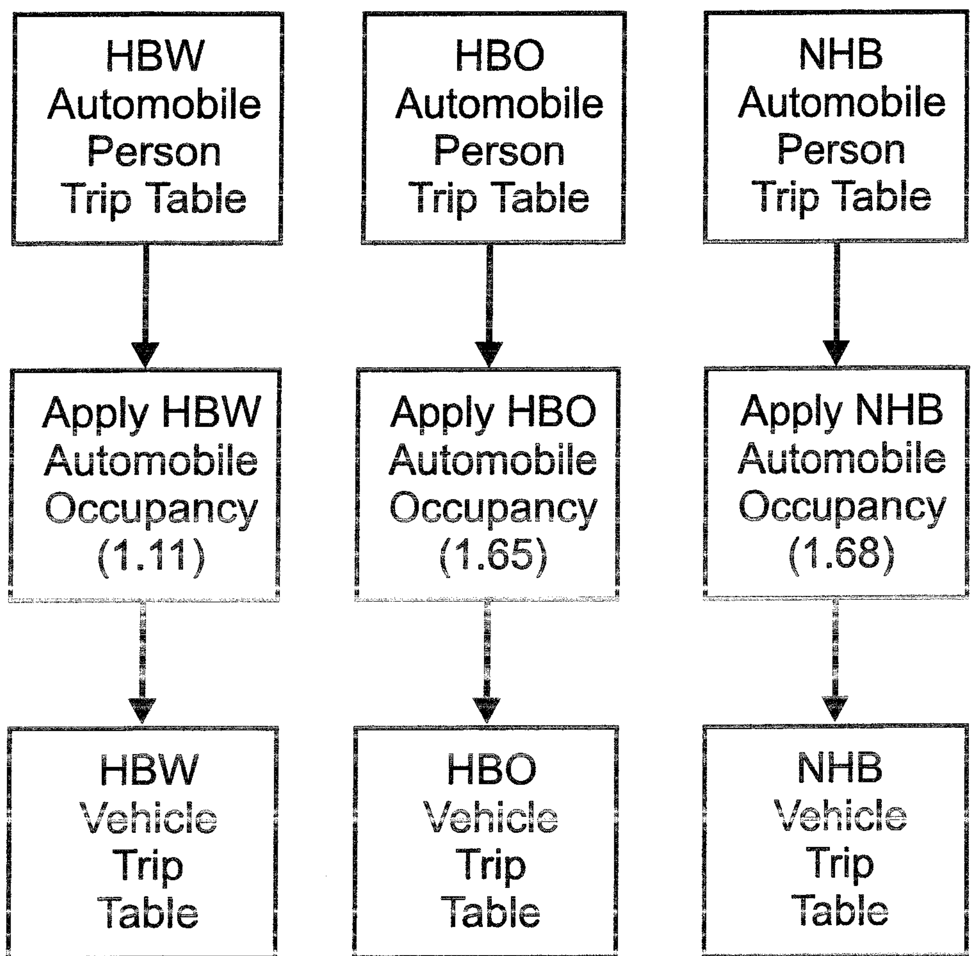
The second approach is time-of-day modeling between mode split and trip assignment. This procedure is used less widely as the factors must be developed from travel surveys. Peak period factors are applied to the mode-specific trip tables produced by the mode split model. These time-specific trip tables are used as inputs to time-period-specific trip assignments. Obviously, the highway and transit network link data (capacity and speed) must be coded appropriately for the time-specific assignments. Four time periods typically are used: overnight, morning peak, midday, and afternoon peak. Daily (24-hour) traffic volumes may be produced by adding the results of the four time-period assignments. P&A formatted trip tables are factored. It is important to understand that applying the directional split factors to the P&A daily trip tables by trip purpose and by mode converts the P&A trip tables to O&D trip tables. This method of time-of-day modeling between mode split and trip assignment is summarized in the figure.

The data to develop the factors require the distribution of trips by time period, by trip purpose (HBW, HBNW, and NHB), and by direction (P to A or A to P). These data are obtained from the analysis of travel surveys. The P&A formatted trip tables are multiplied by the appropriate factors to produce balanced O&D trip tables. These trip tables then are ready to be assigned to time-of-day networks. Time-of-day networks require that the link capacity be adjusted to reflect the capacity appropriate to the time period; for example, the peak 60 minutes, the peak 90 minutes, or the peak 120 minutes, so that the volume delay functions used in the equilibrium assignment algorithm will function correctly.

Notes:

Converting Person Trips to Vehicle Trips

- **Apply Automobile Occupancies**



Converting Person Trips to Vehicle Trips

- **APPLY AUTOMOBILE OCCUPANCIES**

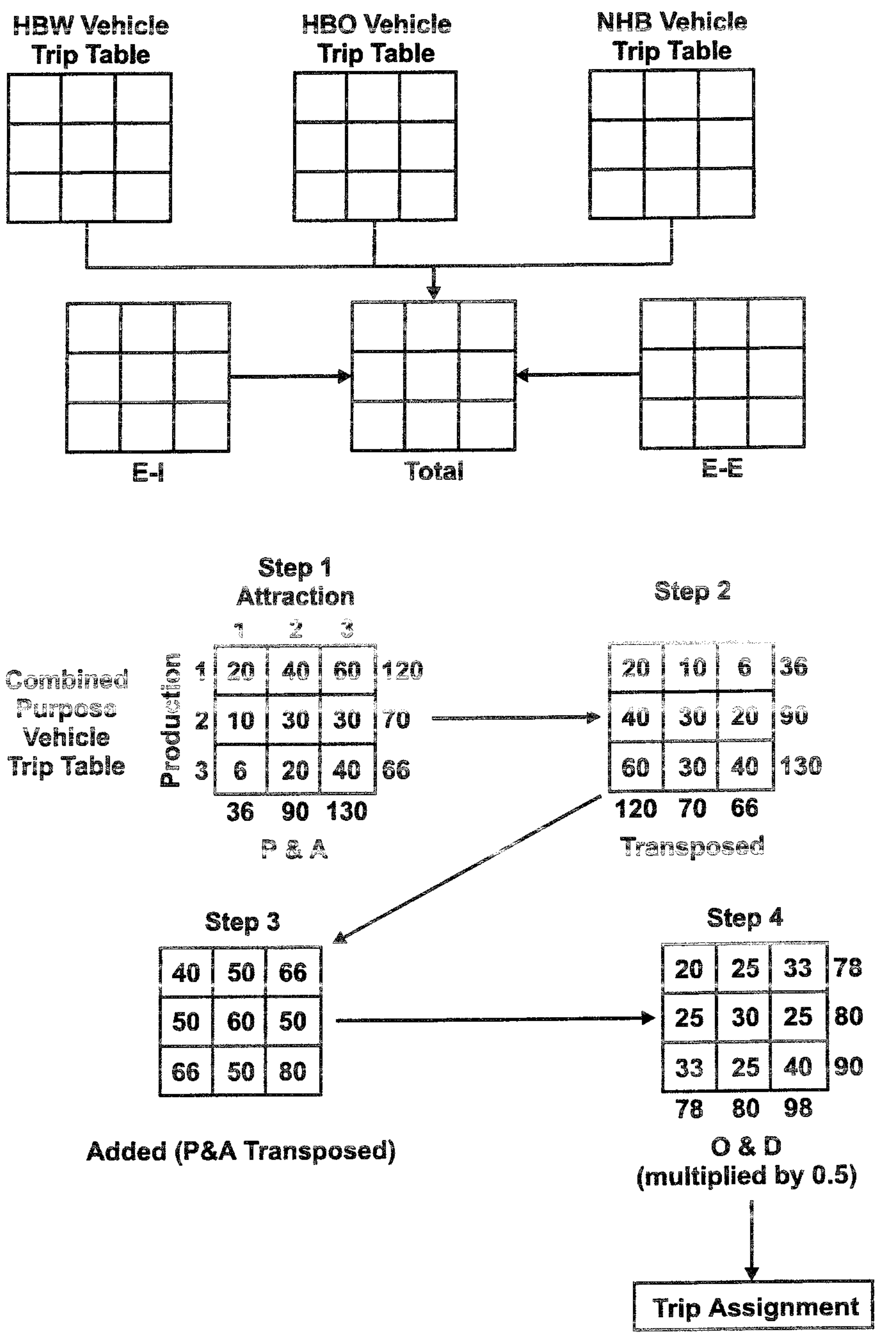
If trips are not split into different automobile occupancy trip tables in the mode split step (single occupant, two-person carpool, three+ person carpool), it is necessary to convert automobile person trip tables into vehicle trip tables. To make the conversion, we apply an automobile occupancy which represents, by purpose, the average number of persons per vehicle for the model area. These occupancies are derived from household travel surveys by dividing the number of person trips for a trip purpose by the number of vehicle trips for that trip purpose.

Average auto occupancies for the U.S. based on the 1990 NPTS are:

HBW	1.11
HBO	1.65
NHB	1.68

Notes:

Converting Productions and Attractions to Origins and Destinations



Converting Productions and Attractions to Origins and Destinations

If time-of-day modeling is not performed, it is necessary to convert the 24-hour P&A trip tables for each trip purpose and for each mode, that are the output of the mode split step, to O&D trip tables before assignment to a highway or transit network. The sum and switch procedure described is done for each mode separately. First, the P and A trip tables for each purpose are added together. This produces a 24-hour trip table for all trip purposes. Second, another trip table is produced by transposing the rows and the columns of the trip table. Thirdly, the two trip tables are added together. Fourthly, the resulting trip table is multiplied by 0.5. This procedure assumes that, over the 24-hour period, half the trips will be in the P to A direction and half the trips will be in the A to P direction. For most people this will be true for any given 24-hour period. The result is a 24-hour trip table in O&D format that is ready for trip assignment. This procedure is illustrated in the figure.

Notes:

Inputs and Outputs

Inputs to time-of-day modeling after trip assignment:

- Time-of-day factors, by area type and by facility type
- Directional split factors, by area type and by facility type

Output: **Link-level, time period traffic volumes by direction**

Inputs to time-of-day modeling between mode split and trip assignment:

- Time-of-day factors, by trip purpose and by mode
- Directional split factors, by trip purpose and by mode

Output: **Time period trip tables, by purpose and by mode, in O&D format**

Inputs and Outputs

Inputs to time-of-day modeling after trip assignment:

- Time-of-day factors, by area type and by facility type, and directional split factors, by area type and by facility type.

Inputs to time-of-day modeling between mode split and trip assignment:

- Time-of-day factors, by trip purpose and by mode, and directional split factors by trip purpose and by mode. The directional split factors are the proportion of trips in the home-to-work direction and the proportion of trips in the work-to-home direction by time period.

Output time-of-day modeling after trip assignment:

- Link-level, time period traffic volumes by direction.

Output time-of-day modeling between mode choice and trip assignment:

- Time period trip tables, by purpose and by mode, in O&D format.

Notes:

Data Collection

For time-of-day modeling after trip assignment:

- 24-hour traffic counts collected across all facility and area types
- Recorded every 15 minutes during collection
- Summarized into time period counts by direction

For time-of-day modeling between mode split and trip assignment:

- Home interview and external station travel surveys
- On-board transit survey for the public transportation mode

Data Collection

For time-of-day modeling after trip assignment, time-of-day factors, by area type and by facility type, are calculated from 24-hour directional traffic counts summarized every 15 minutes. The 15-minute counts are summarized into the time periods used: morning peak, midday, afternoon peak, and overnight.

Time-of-day directional factors, by area type and by facility type, are calculated from 24-hour directional traffic counts summarized every 15 minutes. The 15-minute counts are summarized into the time periods used: morning peak, midday, afternoon peak, and overnight. Note that it is only necessary to know the directional split factors in the peak and off-peak directions by time period. It is not necessary to know which is the peak direction for each link in the network.

For time-of-day modeling between mode split and trip assignment, time-of-day factors by trip purpose and by mode, are calculated from travel surveys. Factors for HBW, HBO, and NHB trip purposes are calculated from home interview travel surveys. Factors for the external–internal and external–external trip purposes are calculated from external station surveys. Factors for the truck trip purpose are calculated from the truck travel survey. Directional split factors are calculated from these same surveys.

Notes:

Forecasting Factors

Forecasting Future Year Factors

- Assume time-of-day and directional split factors remain constant between the base year model and the forecast year models

- Some peak spreading will occur during the AM and PM peaks, and adjustments may be made to future year factors

Forecasting Factors

FORECASTING FUTURE YEAR FACTORS

The typical practice is to assume that the time-of-day and directional split factors, whether applied after trip assignment or between mode split and trip assignment, remain constant between the base year model and the forecast year models. In reality, one expects that some peak spreading will occur during the morning and afternoon peaks as traffic volumes and congestion levels increase. So the modeler may choose to make some adjustments to the time-of-day factors for the forecast years.

Notes:

Example Factors

Time-of-Day Analysis for the Houston/Galveston Model

Network Size

- 8 counties
- 2,598 internal TAZs
- 45 external station TAZs
- 800 transit TAZs for transit mode split analysis
- 18,600 one-way links that represent:
  - 500 centerline miles of freeway
  - 5,000 centerline miles of arterials and collectors
  - 10,200 centroid connectors

Example Factors

Time-of-day factors and directional split factors developed for the Houston/Galveston travel model are provided as an illustration. The Houston-Galveston travel model covers a large geographical area and has a large number of internal TAZs and external station TAZs. The size of the network is highlighted on the opposite page.

Notes:

Example Factors

Time-of-Day Analysis

Houston/Galveston Model Time-of-Day Factors

Vehicle Trip Table Factoring Information by Time Period

Purpose	PERCENT OF TRIPS			
	6:30 to 8:30	8:30 to 3:30	3:30 to 6:30	6:30 to 6:30
HBW	34.78	15.26	29.47	20.49
HB School	45.20	30.32	18.56	5.92
HB Shop	3.96	37.50	29.91	28.63
HBO	11.99	31.53	26.03	30.45
NHB	6.95	60.59	22.75	9.71
Truck/Taxi	13.04	57.68	20.19	9.09
External	9.61	41.81	22.92	25.66

Example Factors

In the Houston/Galveston travel model the HBO trip purpose is divided into three separate trip purposes: HB school; HB shop; and HBO. The time-of-day factors are shown in the table.

From the table, the proportion of the 24-hour HBW trips that occur during the 6:30 a.m. to 8:30 a.m. morning peak period is 34.78%. The portion of the 24-hour HB trips that occur during the 8:30 a.m. to 3:30 p.m. off-peak period is 15.26%. The row percentages total to 100%. Notice that the highest percentage of NHB trips occur during the 8:30 a.m. to 3:30 p.m. off-peak period.

Notes:

Example Factors

Time-of-Day Analysis

Houston/Galveston Model Time-of-Day Factors

Vehicle Trip Table Factoring Information by Time Period

Purpose	Percent of Trips in P to A Direction by Time Period			
	6:30 to 8:30	**8:30 to 3:30**	**3:30 to 6:30**	**6:30 to 6:30**
HBW	98.0	66.6	2.2	58.3
HB School	99.3	20.9	7.8	26.4
HB Shop	87.7	49.4	27.5	31.2
HBO	89.3	58.3	30.4	34.1
NHB	50.0	50.0	50.0	50.0
Truck/Taxi	50.0	50.0	50.0	50.0
External	55.0	50.0	45.0	50.0

Example Factors

The directional split factors are shown in the table.

From the table, during the morning peak period, the percentage of trips in the home-to-work direction is 98.0%. This means that 98% of the persons making work trips during the morning peak are going from home to work. Although not shown in the table, 2% of the persons making work trips during the morning peak are going from work to home.

As a result of applying these directional factors, the P&A trip table by trip purpose and mode is converted to an O&D trip table purpose and mode.

Notes:

References

1. Cambridge Systematics, Inc. *Time-of-Day Modeling Procedures, State-of-the Practice.* Prepared for the Travel Model Improvement Program, U.S. DOT and O.S. EPA, October 1997.