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Procedures Manual for Estimating Emission Reductions from Voluntary Measure and Commuter Choice Incentive Programs

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Voluntary Measure and Commuter Choice Incentive Programs

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1. Introduction

This manual describes a set of procedures that can be used to evaluate voluntary mobile source emission reduction and commuter choice incentive programs for State Implementation Plan (SIP) and employer-based commuter choice programs. To simplify their use, they have been implemented in a spreadsheet model, entitled COMMUTER, whose operation is explained in a companion report entitled "COMMUTER Model User Manual for Analysis of Voluntary Mobile Source Emission Reduction and Commuter Choice Incentive Programs."

The procedures are intended to be simple to apply, with data requirements the minimum necessary to evaluate alternative programs. At the same time, the analytical techniques employed in these procedures are consistent with existing state-of-the-practice travel modeling techniques widely employed by transportation professionals. The calculation methodologies are largely based on those used in the Federal Highway Administration Travel Demand Management Evaluation Model (FHWA TDM Evaluation Model), developed by COMSIS Corporation in 1993. This model has been widely applied in the evaluation of employer-based TDM programs for the purposes of calculating travel impacts.

The analytical process described in this report is illustrated by the flowchart in Figure 1-1. The basic sequence of steps in this process can be used to assess travel impacts without use of the COMMUTER model. The sequence of procedural steps is outlined below.

- First, adjust the baseline (existing) mode shares to reflect the impacts of support and incentive programs such as rideshare matching and provision of bicycle facilities. To make the adjustments, apply mode shift factors from lookup tables that have been compiled from the literature and national experience.

- Once the impact of support and incentive programs have been accounted for, use travel modeling techniques to estimate the impacts of strategies related to travel time or cost savings on mode choice. Support and incentive programs include site-specific employer programs such as on-site transit pass sales, rideshare matching, and guaranteed ride home programs. Those strategies that can be measured by savings in travel times and costs include transit use frequency, high occupancy lanes, and transit fare reductions.

Figure 1
Overview of Calculation Procedure
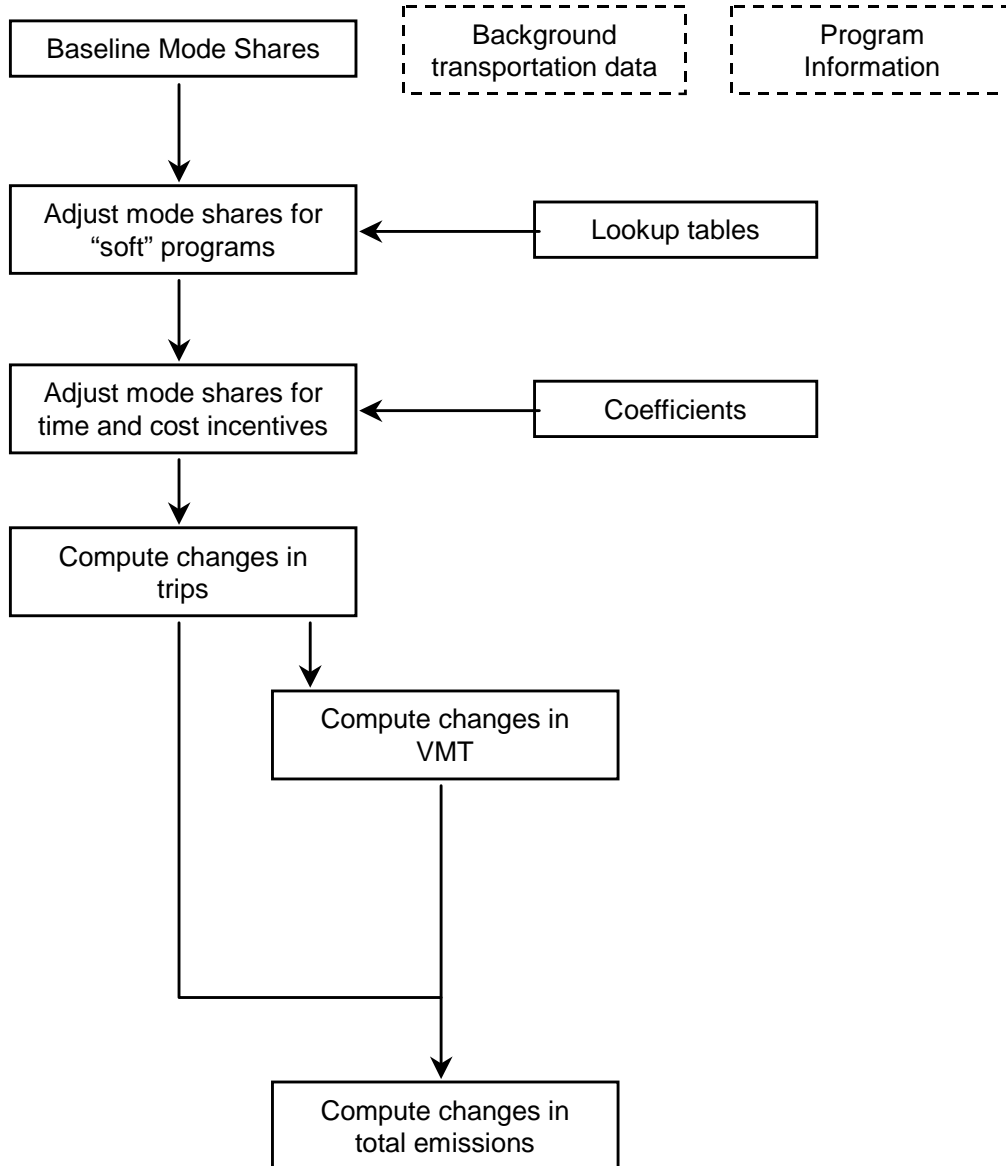
- Convert the changes in mode shares to changes in motor vehicle trip ends. Use the average trip length by mode to convert these changes in trip ends to changes in vehicle miles traveled (VMT).

- Use predefined sets of emissions factors to estimate the emissions impacts.

The following sections discuss each step in the process in greater detail for both model- and manually derived applications. The discussion covers definitions of terms, assumptions and analytical techniques, and coefficients and parameters that enter the calculations.

It is <u>highly recommended</u> that analysts use locally derived values for the parameters whenever possible to be consistent with local travel behavior characteristics in the metropolitan area of analysis. In the absence of local data, the analyst may use default values for program effectiveness that have been provided in this manual and built into the spreadsheet model.

The following sections provide guidance in setting parameter values. Typically, employers will want to use parameter values or values provided by their local transportation planning agency, if available, before relying on the defaults listed in this guidance.

<p align="center">###</p>

2. Overview of the COMMUTER Model Analysis Procedure

What is the COMMUTER Model?

COMMUTER is a spreadsheet-based computer model that has been developed by EPA to help areas obtain air quality credit from VMEP-type programs. It is specifically intended to calculate the travel and emissions effects that might result from implementation of voluntary employer transportation management programs. Areas may claim up to 3% of their mobile source emission reductions from regional implementation of such programs, and the COMMUTER model is designed to help areas justify their credit claims by providing quantitative justification of the associated reductions. The tool may be used by regional planning or air agencies who are interested in pursuing this VMEP credit on a region-wide basis, or by individual employers who may be seeking tax credit for implementing a voluntary commuter choice incentive program.

Conventional transportation analysis tools normally used for regional planning and SIP development are not well suited to the VMEP analysis task for several reasons, the most important of which are the following:

- Traditional transportation analysis tools are unable to address many of the voluntary commuter-choice measures, such as rideshare matching support or alternate work schedules, in their structure; and

- Use of the traditional analysis tools is a complex and labor-intensive process. This would limit analysis to only trained specialists, thereby excluding employers and other interested groups from engaging in the process, and dramatically cut down on the trial-and-error nature of determining what particular combination of measures is the most effective and acceptable for a given VMEP program.

COMMUTER offers a substantial savings in time and effort over the traditional approach by employing some key shortcuts in the amount of data used and the number of micro-level calculations that are performed. The result is a conscious but judicious tradeoff of some accuracy for a significant increase in ease and flexibility for the user.

Conventional Analysis Methods

To understand the nature and operation of the COMMUTER model approach, it is helpful to contrast it with the traditional approach. Figure 2-1 shows how a mobile source emissions analysis would be done in normal practice. The process generally consists of first estimating the transportation effects of a particular policy, program, or improvement in the suite of models collectively known as the "four-step" process. This results in a revised summary of vehicle trips, VMT, and operating speeds, which then become the inputs to the emissions modeling procedure. Vehicle travel activity is mated with emission production rates, typically through the latest version of EPA's MOBILE emissions model (EMFAC in California), which applies emissions factors that have been specially adjusted to reflect local vehicle, regulatory, and climatalogical conditions.

Figure 2-1
Traditional Transportation and Emissions Analysis Process
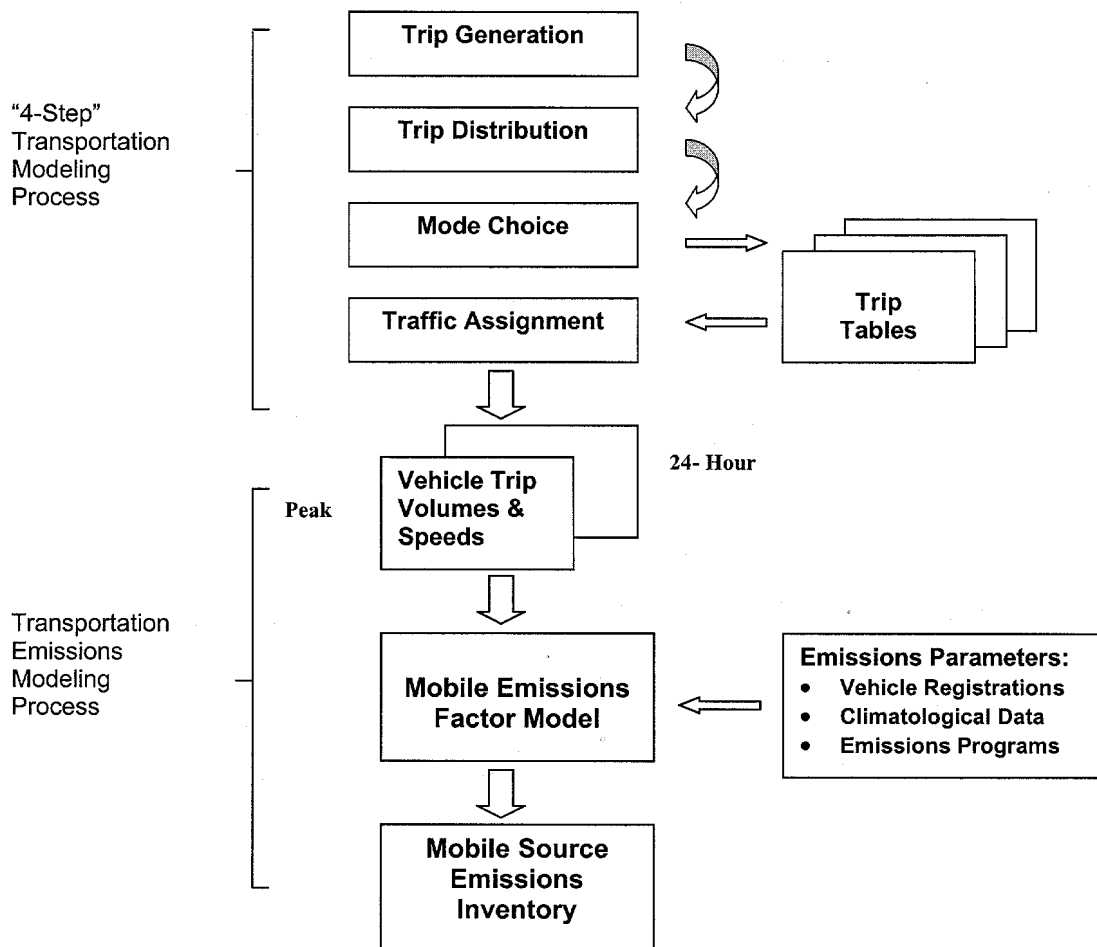
The four-step transportation analysis process is so named because of its separate consideration of the elements of Trip Generation, Trip Distribution, Mode Choice and Traffic Assignment.

- The **Trip Generation** step converts population, employment, income, vehicle ownership, land use and other factors into an estimate of the number of trips that will be made by households (productions) or attracted by economic and personal activities (attractions).

- **Trip Distribution** then determines "where" households will travel to meet their various needs, or conversely, "from where" travelers will come to serve the various economic or personal attractions. The result is a set of tables (or matrices) that depict trip flows between origins and destinations. The origins and destinations in these "trip tables" correspond to specific geographic "zones" defined by the planning agency. In a typical metropolitan area, there is likely to be more than 1,000 such zones, meaning that their combined function as both origins and destinations can result in several thousand origin-destination pairs for which trip flows have been calculated, and upon which analysis may be necessary. Also, trip tables are generally developed for separate trip purposes, the most common of which are Home-Based Work, Home-Based Non-Work, and trips that are not based from home, so-called Non-Home-Based trips.

- Trip tables are then processed through a **Mode Choice** step, which predicts the travel modes that will be used to make the various trips for each origin-destination pair and for each trip purpose type (work, non-work, etc.). The rate of use of particular modes (usually auto driver, auto passenger, and transit) is based on which of these alternatives is available, the comparative service offered by each alternative, and characteristics of the traveler. This determination is usually made through a "mode split" model, and is calculated separately for each origin-destination pair, resulting in a new (additional) set of trip tables for private vehicle trips and transit person trips.

- Once vehicle trip volumes by origin-destination are known, the final step is to distribute these trips onto the regional highway system in a process known as **Traffic Assignment**. The computer is asked to overlay the regional trip tables onto the system of freeways, arterials, collectors, and local streets and roads, and to determine which combination of routes will be taken to complete the trips most efficiently. To do this, the computer must have information on the carrying capacity of each facility (on a segment-by-segment basis). Trips are incrementally loaded onto the highway network to see what volumes and travel speeds will result, and then reassigned to new paths in progressive iterations until all travelers are realizing the most efficient (minimum travel time) path for their particular trip given the overall volume of travelers. Major urban areas will generally perform such a traffic assignment for an average 24-hour day, and also for a case that represents peak period or peak hour conditions. The peak period traffic assignment is crucial in identifying congestion

conditions and in studying both work travel and competitive mode choice situations.

The outputs of the transportation modeling process are then converted for use in the **MOBILE emissions model**. MOBILE requires the user to supply information on the local context in order to tailor the emissions rates appropriately to the individual area. The information required includes composition of the regional vehicle fleet (by age and size group) from vehicle registration and usage data; various climatological data, including temperature and season; and existing emissions control programs in place, such as reformulated fuels or inspection and maintenance programs. An important element in adapting the MOBILE model and emissions factors to the region is also applying *speed correction factors* to the respective emissions rates to reflect different rates of emissions that occur at different operating speeds. The transportation inputs are used to make this adjustment, which may be as simple as a single across-the-board adjustment for all travel, or specific adjustments for VMT occurring on freeways vs. other facilities and under peak or off-peak conditions.

How the COMMUTER Model Approach is Different

From the above, one can begin to see the value of having a simpler and more versatile procedure for analyzing VMEP and commuter choice program strategies. While all of the steps outlined above do not have to be repeated for every analysis using the conventional models, it is still necessary to change the input data for each origin-destination pair in the regional trip tables that will be affected by the policy or program measure, re-estimate the modal split, and then redo the traffic assignment step in order to get the new speed and VMT impacts required by MOBILE.

The COMMUTER model approach simplifies the quantification requirements for VMEP programs by making selective simplifications, as well as enhancements, to the conventional four-step model oriented process. The procedure is heavily based on the Federal Highway Administration's Travel Demand Management Evaluation Model (FWHA TDM Model), developed in 1993 for a similar purpose, to facilitate analysis of TDM programs and strategies for congestion management and air quality programs.[*] Prior to its acceptance by the FHWA for national distribution as a planning tool, the TDM model underwent significant sensitivity testing, and has been applied widely across the country by planning agencies, transportation agencies, and employers or employer

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[*] The TDM Evaluation Model was developed by COMSIS Corporation in 1993 in conjunction with a comprehensive program of research and development of reference and guidance tools by the Federal Highway Administration and Federal Transit Administration. Additional information of potential value to VMEP Tool users may be found in the related reports from that research effort: *Implementing Effective Travel Demand Management Measures: Inventory of Measures and Synthesis of Experience*, DOT-T-94-02 (September 1993), *Guidance Manual for Implementing Effective Employer-Based TDM Programs,* DOT-T-94-05 (November 1993), and *Guidance Manual for Areawide Travel Demand Management Programs,* (October 1992).

organizations. It was therefore viewed as a good base from which to build the COMMUTER model.

The decision to build a new procedure to support VMEP program analysis needs and requirements, rather than simply modifying and adopting the FHWA TDM model, was based on the following factors:

- The FHWA TDM model was not designed to calculate emissions.

- The FHWA TDM model, while much simpler than the four-step models, was still designed primarily to work with trip tables, and was also seen as more complex than some members of the target audience would be able to work with.

- The FHWA TDM model lacked a modern "Windows"-type user interface, meaning the user would not be able to use a mouse or other convenience procedures to ease application.

- It was seen as desirable to recheck and, as necessary, update or enhance the calculation procedures or impact values coded into the TDM model.

The resultant COMMUTER model has the structure and general features pictured in Figure 2-2. It is essentially a three-step procedure:

1. The user establishes a baseline by supplying essential information on local conditions.

2. An analysis scenario is selected from among available options.

3. Impacts on vehicle trip making, VMT, and its distribution between peak and off-peak travel periods are calculated and used to estimate the change in emissions of VOCs, CO, and NOx.

Each of these steps is described briefly below, simply to provide an introduction to how the overall technique operates. Subsequently, each remaining numbered section of this Procedures Manual describes in some detail each of the individual steps and procedures. The objective is to provide the analyst with a detailed explanation of how the model is operating, the assumptions employed, and the data and methods that are used to calculate the particular impact. Numeric examples are provided in the individual topic sections to illustrate each module and its calculation procedure, supplemented in most cases by sample applications across a range of starting conditions or values of the particular measure to provide insight as to the measure's and the model's sensitivity. Uncertainties, where important, are identified and described.

Figure 2-2
COMMUTER Estimating Procedure

① **Establish Baseline:**

• Area Size/Setting	• Average Trip Lengths
• Analysis Scope	• Peak Period Duration
• Employment Base	• Peak/Off-Peak Work Trips
• Existing Mode Split	• Peak/Off-Peak VMT
• Vehicle Occupancy	• Peak/Off-Peak Speeds

Strategy   **Procedure**   **Degree of Impact**

Define Scenario & Compute Travel Impacts

② **Employer TDM Support**
- Site Specific
- Areawide

⇒ *Adjust mode shares and re-normalize* ⇐ Look-Up Tables

③ **Alternative Work Schedules**
- Flex or Staggered Hours
- Compressed Work Weeks
- Telecommuting

⇒ *Adjust peak/ off-peak trip distribution* ⇐ Look-Up Tables

④ **Travel Time Improvements**
- Walk Access
- Transit Service Improvements

⇒ *Logit Pivot-Point Model* ⇐ Mode Choice Coefficients

⑤ **Travel Cost Changes**
- Parking Pricing
- Modal Subsidies
- Other/General

⇒

Calculate Emissions Impacts

Change In:
- **Peak/Off-Peak VMT**
- **Peak/Off-Peak Trips**

⇒ ⑥ **Emissions Estimating Procedure** ⇐

Emissions Parameters
- Vehicle registrations
- Climatalogical
- Emissions Programs
- Peak/Off-Peak Average Speeds

Scenario Emissions Reductions
- Δ VOCs, Peak/Off-Peak
- Δ CO, Peak/Off-Peak
- Δ NOx, Peak/Off-Peak

This Procedures Manual <u>does not</u> provide the step-by-step guidance on the actual use of the COMMUTER model. This help may be found in the **COMMUTER User's Manual**, which provides a practical introduction to each of the model features, accompanied by illustrations of the respective model screens or functions, with direct instructions on what data are needed and where and how they should be entered.

Baseline Data Requirements

The COMMUTER user is required to provide some basic information to the model in order to establish a starting point, or baseline, from which to measure changes, as well as to communicate some important local conditions that are used in performing the analysis. This information consists of the items shown in box number ① in Figure 2-2. The required items are summarized briefly below.

- **Area Size and Type:** Qualifies the area as Large (over 2 million), Medium (750,000 to 2 million), or Small (under 750,000), and whether the analysis is being directed at the regional downtown core, a medium-density area or activity center, or a low-density suburban area.

- **Analysis Scope:** Whether the analysis is being applied at the scale of an entire region, for a specific employment site, or some variation in between.

- **Employment Base:** Since the analysis is being directed at work travel, it is important to know the size and composition of the regional (or other application scale) employment base. In particular, it is important to know the number of employees working in "Office" as opposed to "Non-Office" occupations, and also the proportion of this base that is expected to be <u>affected</u> by the VMEP strategies. A discussion of the important distinction between <u>total</u> and affected employment is presented in Section 3.

- **Starting Modal Split:** The existing modal shares for work trips in the study area, specifically percent of persons making work trips by auto drive alone, auto carpool, vanpool, transit, walk, bicycle, and other .

- **Vehicle Occupancy:** Average number of persons traveling in a carpool unit or a vanpool.

- **Average Trip Length:** Average trip length (distance), for all work trips (including transit), and separately for vanpool, bicycle and walk.

- **Peak Period Duration:** Length of weekday peak travel period in hours.

- **Peak/Off-Peak Work Trips:** Percent of daily work trips that are made during peak travel periods.

- **Peak/Off-Peak VMT:** Total daily VMT from work trips that occurs during peak and off-peak travel periods.

- **Peak/Off-Peak Travel Speeds:** Average speeds on freeways and non-freeway roads, during peak and off-peak travel periods.

The need for this information is explained in greater detail in Section 3, and specific instructions on where to obtain the information and how to use it in the model are spelled out in the Users' Guide. Default values are provided in the model for many of the items, although users are strongly urged to enter their own unique information. Some special instructions apply to users of the COMMUTER model who are regional planning agencies vs. employers and other less experienced in transportation planning methods and data.

Selection of Strategies and Development of Scenarios

The COMMUTER model allows the user to select from and test a variety of strategies. As shown in Figure 2-2, these include (as numbered in the diagram):

② **Employer TDM Support Strategies:** Non-monetary inducements to encourage employees to use alternative modes rather than drive alone. These include rideshare matching services, vanpool formation assistance, on-site transit information and/or pass sales, transportation coordinators, guaranteed ride home.

③ **Alternative Work Schedules:** Arrangements such as flexible or staggered work hours, compressed work weeks, and telecommuting.

④ **Travel Time Improvements**: On-site or adjacent area modifications to improve access to work sites from transit, or by walking or biking. Also includes preferential (close-in/reserved) parking for carpools or vanpools, and improvements to transit service.

⑤ **Travel Cost Changes**: Measures such as imposition of parking fees, differential rates or discounts for carpools or vanpools, transit fare subsidies, or inspecific modal incentives or disincentives to any or all modes.

Specific strategy options are discussed in Section 4 for Employer TDM Support, in Section 5 for Alternative Work Schedules, and Section 6 for Travel Time Improvements and Travel Cost Changes. With few limitations, the user may mix and match any number or combination of these strategies within a given "scenario", and obviously can create and test as many scenarios as desired. By so doing, the user will gain insight into which strategies are the most effective for their particular situation, and will discover the flexibility they may have to achieve their desired transportation management goal in more than one way.

Computational Methods for Estimating Transportation Impacts

The COMMUTER model escapes the technical and resource intensity of the traditional four-step modeling approach by taking some calculated shortcuts. These shortcuts retain the essence of the full-blown approach, but simplify the effort for a typical VMEP analysis by an order of magnitude. Of course, because these shortcuts cut back on the many minute calculations that are normally done in a trip-table-based analysis, a certain degree of uncertainty is introduced by replacing a large number of individual computations with a single "aggregate" calculation. However, given the modest increment of change typically expected from VMEP programs (and for which EPA is prepared to grant credit), the COMMUTER model is seen as a reasonable compromise between ease of use and accuracy.

Like the FHWA TDM model on which it is based, COMMUTER's simplicity derives from an "incremental" type of analysis procedure, often referred to by transportation planners as "pivot-point" analysis. Rather than rerun the entire suite of transportation models in the four-step process (or at least the mode choice and the assignment steps), which entails making changes in the service variables and computing impacts for each affected origin-destination pair in the regional trip tables, a pivot-point approach simply extrapolates from the existing condition, or baseline. The degree of incremental adjustment in this extrapolation depends on the current modal share balance, the types of strategies that are being tested, to what modes and with what intensity they are being applied, and what is known about the relationship, or sensitivity, between the particular strategy (or service characteristics it affects) and demand for the mode. For modest changes in mode shares, such as would be expected with Travel Demand Management or VMEP type strategies, this incremental extrapolation is a convenient and acceptably accurate alternative to the more rigorous analysis methods.

There are various ways this incremental adjustment/extrapolation can be done, some much more analytically sophisticated than others.

- **Elasticities:** Applying a relationship derived from observing degree of change in behavior in response to a change in an underlying variable.

- **Share Adjustment Relational Factors:** When formal elasticity relationships have not or cannot be developed because of insufficient data or research on a relationship, or because individual relationships cannot be isolated with statistical confidence, factors may be developed that suggest the type of change that would be expected in mode share based on a particular type of action taking place, which may vary with the type of mode, setting, packaging assumptions with other strategies, presence of a regulation, or type or size of employer.

- **Multimodal Travel Demand Models**: Coefficients may be taken from multimodal travel demand models, and applied either to an individual mode or strategies or to multiple modes and strategies simultaneously.

The preferred approach among these options is the use of coefficient-based travel demand methods. Elasticities can be very helpful as planning aids, since they provide some statistical basis for inferring a relationship between travel demand and a transportation service or cost change. Where elasticities are limited is in being able to take into account the interactive effects that occur when multiple actions are applied or multiple modes are involved. For example, if a setting had two modes—auto and transit—and two strategies were proposed—an auto parking charge along with a 10-minute reduction in transit travel time, an elasticity method would not be able to project the combined effect of these strategies on the subsequent demand for auto and transit. In contrast, a coefficient-based multimodal approach has the ability to look at the combined effects of multiple strategies and deal realistically with the cross-modal effects. The relational factors approach is a fallback procedure when formal statistical relationships have not yet been developed.

As with the TDM model, the COMMUTER model uses two of the above procedures for calculating travel response to VMEP strategies:

- **Logit Pivot-Point Model:** A multimodal pivot-point model using coefficients and computational procedures from accepted logit-based mode choice models; and

- **Look-Up Tables**: Relational factors from empirical research, arrayed in look-up tables where increments of change are associated with particular types of programs, reflecting different application assumptions, levels of intensity, and setting.

Figure 2-2 classifies the various strategies incorporated in the COMMUTER model into four groups. The classification system mainly relates to how the strategies are analyzed in the model. The first two—Employer TDM Support Programs (2), and Alternative Work Schedules (3)—are analyzed using relational factors in look-up tables, with a normalization procedure applied to the adjusted shares to ensure that changes are proportionate across the available alternatives and do not allow final choices to exceed 100%. The strategies that involve changes to either travel time or cost, however,— Travel Time Improvements (4) and Travel Cost Changes (5)—are analyzed through the more rigorous logit pivot-point procedure. Each of these is described briefly below, and then in more detail in the individual report section that deals with that strategy type.

Share Adjustments for Employer Support TDM Actions Using Look-Up Tables - While virtually any attribute that plays a role in travel choice can be included in the structure of a logit model, usually the models are limited to only factors that are related to travel time or cost. Partly this is because there has not been great interest in trying to include such diverse and specialized strategies as carpool matching programs and employer transportation coordinators in regional travel models, and partly it is difficult to incorporate these relationships within standard mode choice models for reasons of available or appropriate data, or being able to demonstrate a functional relationship with acceptable statistical confidence. Transportation analysts and economists have commonly concluded that the biggest changes in travel behavior are those induced by changes in the

underlying economics among the alternatives, such as policies that try to lessen the travel time disadvantage of using transit or carpool over driving alone, or seeking parity in the cost of travel by raising the cost of driving alone or discounting the cost of traveling by alternative modes.[*]

As with the TDM Model, the COMMUTER model categorizes the various Employer TDM Support Measures in group 2 into four discrete categories of effort, presented as "levels." Each level constitutes a program of actions undertaken by the employer that is intended to enhance the attractiveness of alternative modes and thereby increase the likelihood that employees will use that mode over driving alone. Level 1 programs reflect minimum effort by the employer, and hence produce the smallest change in behavior, whereas Level 4 programs reflect the maximum effort and maximum travel behavior impact. Specific named strategies describe what is assumed to be provided in each level, with higher-level programs generally including everything that was offered in the lower-level program, as well as some new measures or special enhancements.

There are individual support programs for each alternative mode except pedestrian: Carpool, Vanpool, Transit, Bicycling. The support programs are also specific and relevant to the individual mode, such as on-site pass sales being part of the Transit support program. Invoking any of the Support Programs triggers a procedure that adds an increment of mode share to the mode that is receiving the support, with the adjustment increments being greater for higher levels of each program. The adjustment values are stored in look-up tables for easy access and use by COMMUTER. A simple illustration of how this analysis would be done in the COMMUTER model is provided in Figure 2-3.
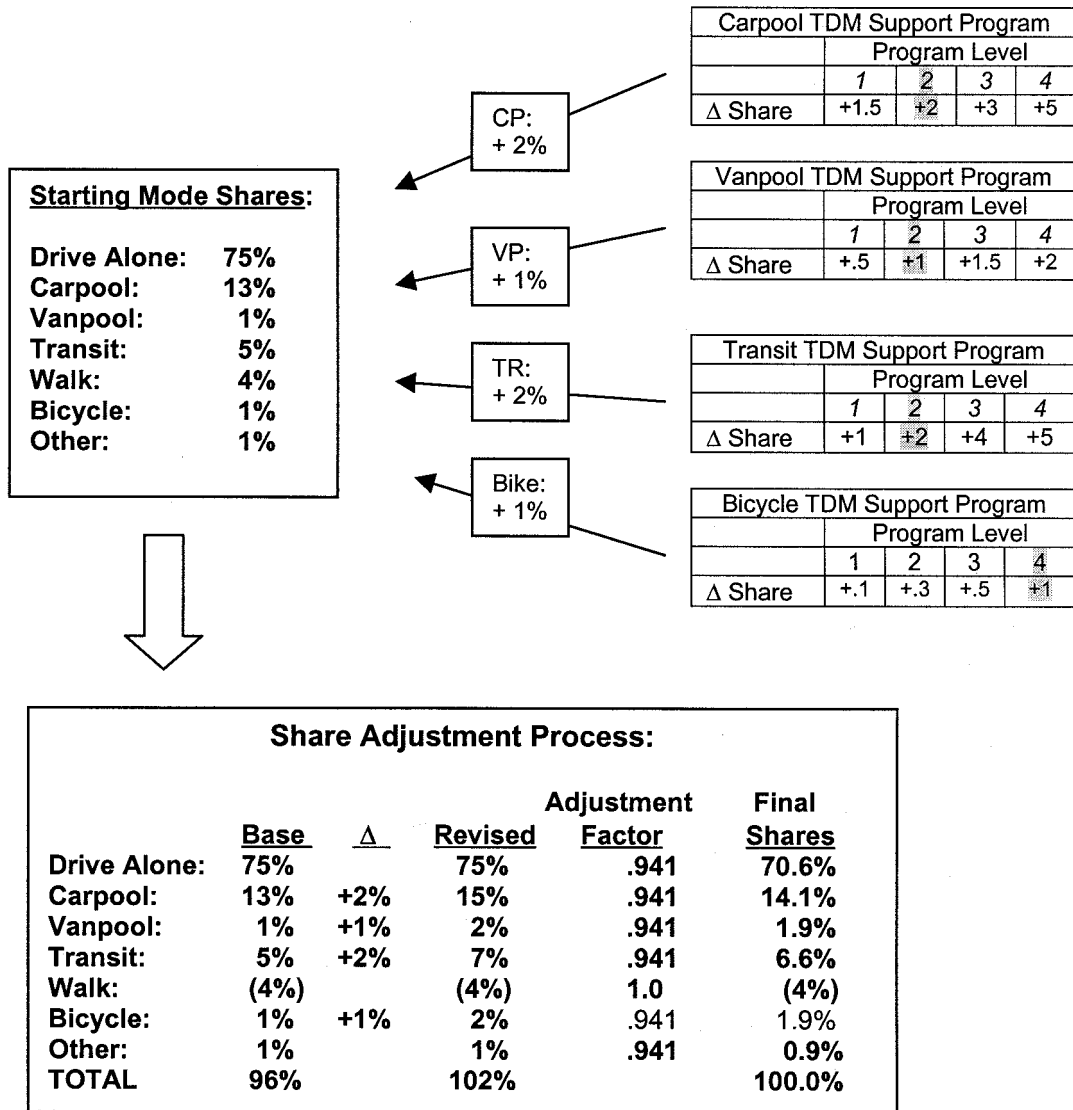
When a scenario is designed that includes support measures for more than one mode at a time (a common occurrence), the COMMUTER model must distribute the impact across the modes. The model does this by adding the shares to the modes being targeted, and then readjusting the shares of all modes—those targeted and those not—such that the total for all modes once again equals 100%. This requires a proportionate adjustment across all modes, which means that modes with the largest starting shares (such as drive alone) when asked to forfeit shares will lose the greatest absolute number of users, while small share modes (like vanpool) will lose the least. As part of the normalizing process, even the targeted mode will have to forfeit some of its new share to ensure proportionate redistribution.

In Figure 2-3, a starting balance of modal shares is shown in the box at the upper left, with a pending program of TDM Employer Support measures described on the right. The

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[*] See, for example Part III: Synthesis of Findings in the report: COMSIS Corporation, *Implementing Effective TDM Measures*, for the Federal Highway Administration, DOT-T-94-02. Section 3 (September 1993). Also, in work done for the California Air Resources Board and the South Coast Air Quality Management District by COMSIS in 1993 for the purpose of developing new plan development and plan review software for Employer Trip Reduction Programs under Regulation XV, extensive analysis of Reg. XV employer plan data from SCAQMD files coupled with new survey data from 43 California employers failed to find significant impacts on travel arising from a variety of popular non-monetary support type programs offered by employers.

Figure 2-3
Illustration of Share Adjustment Process

Starting Mode Shares:

Drive Alone:	75%
Carpool:	13%
Vanpool:	1%
Transit:	5%
Walk:	4%
Bicycle:	1%
Other:	1%

CP: + 2%

VP: + 1%

TR: + 2%

Bike: + 1%

Carpool TDM Support Program

	Program Level			
	1	2	3	4
Δ Share	+1.5	+2	+3	+5

Vanpool TDM Support Program

	Program Level			
	1	2	3	4
Δ Share	+.5	+1	+1.5	+2

Transit TDM Support Program

	Program Level			
	1	2	3	4
Δ Share	+1	+2	+4	+5

Bicycle TDM Support Program

	Program Level			
	1	2	3	4
Δ Share	+.1	+.3	+.5	+1

Share Adjustment Process:

	Base	Δ	Revised	Adjustment Factor	Final Shares
Drive Alone:	75%		75%	.941	70.6%
Carpool:	13%	+2%	15%	.941	14.1%
Vanpool:	1%	+1%	2%	.941	1.9%
Transit:	5%	+2%	7%	.941	6.6%
Walk:	(4%)		(4%)	1.0	(4%)
Bicycle:	1%	+1%	2%	.941	1.9%
Other:	1%		1%	.941	0.9%
TOTAL	96%		102%		100.0%

example suggests that the employer (or group of employers) will implement Level 2 Carpool, Vanpool, and Transit support programs, and a Level 4 Bicycle support program. The lookup tables show these options being selected for the test scenario: the Level 2 Carpool program contributes a 2% increase to the current 13% carpool mode share, Level 2 Vanpool contributes a 1% increase to the existing 1% vanpool, Level 2 Transit contributes 2% to the current 5% share, and Level 4 Bicycle contributes 1% to the current

1% bike share. As shown in the Share Adjustment Process box in the lower half of the figure, the Support Program share increments are added to the base shares, and a new total computed. Obviously, the new total with the program increments added will exceed the total for the baseline distribution; the baseline would normally total 100%, except

that a special treatment is provided for the Walk mode. Walk is the only mode for which TDM support enhancements have not been developed, raising the concern that walkers—like solo drivers—can only "lose" ground when support measures are applied to the other alternatives, since those adjustments would otherwise come out of the Walk share of 4%. To prevent this from happening until such time as a set of support factors can be developed for Walk, the Walk mode is kept out of the mode share adjustment process. Its 4% is shown in parentheses in the table, indicating this treatment.

With Walk out of the equation, the baseline mode shares total 96%, and the new mode shares total 102%. An adjustment must be made to re-apportion the gains (or losses for SOV) to account for the reality that (1) the total cannot exceed 100% (96% in this example), and (2) that the modes will "compete" for the new shares. In other words, if an improvement is made to Carpool as an option, it would be expected that it would attract new users not only from solo drivers, but also in some measure from Transit and the other modes if indeed Carpool had received a comparative advantage. And if both Transit and Carpool received improvements, both would be likely to "steal" share from SOV, but also from each other. The procedure to accomplish this redistribution in the COMMUTER model for support programs is to "normalize" the gross adjusted shares. In the example, the previous total of 96% is divided by the equivalent new total, or 102%, producing an adjustment factor of 0.941. Each share—except for Walk—is subsequently multiplied by the adjustment factor to obtain the final revised share expected from this scenario. As may be seen, the biggest adjustment is taken from Drive Alone, which falls from 75% to 70.6%, while Carpool rises from 13% to 14.1%, Transit rises from 5% to 6.6%, Vanpool and Bicycle go from 1% to 1.9%, and Other falls from 1% to 0.9%.

Section 4 provides greater detail on this procedure as it applies to Employer TDM Support Programs. Specifically, the actual look-up reference tables used in the calculations are provided, along with key related assumptions regarding characteristics of the employment base, and special considerations that apply to using the model for an individual employer vs. applying it at a regional or multi-employer level.

<u>Trip Adjustments for Alternative Work Hours Strategies</u> - The procedure is virtually the same as applied to Alternative Work Schedules, except that the changes that are induced are solely to shift the given trip from the peak period to the off-peak period. No mode shifts are calculated in conjunction with these strategies. The benefit in terms of emissions, therefore, is not in the elimination of a trip but in its movement to a less-congested travel period. With less congestion, vehicle speeds will be higher, which will affect the emissions rates in the model. In most cases, as with VOCs, the speed change results in fewer emissions, while in others, say with NOx, a higher speed may increase emissions.

As with the Employer TDM strategies, the COMMUTER contains a separate look-up table for each strategy: Flexible Hours, Staggered Hours, 4/40 and 9/80 Compressed Work Weeks, and Telecommuting. However, unlike the Employer TDM procedure where the user selects a particular "level" of program package and intensity, with the Alternative Work Hours strategies the user indicates only what percentage of employees will be "eligible" for each program type. The procedure then uses this percentage to

determine how many trips are eligible for the given program, e.g., 4/40 work weeks, and applies a factor that calculates how many of these trips will be shifted outside the peak. The trips that are shifted from peak period to off-peak period are shifted *at the current mode split*. In other words, if 75% of all trips in the peak period were Drive Alone, then the model assumes that 75% of those shifted will be Drive Alone, with the remainder comprised of Carpool, Transit, Bike, Walk, etc.

The procedure guards against an illogical number of employees participating in Work Hours programs, to prevent double counting. However, users are able to test the assumption that workers may be eligible for more than one Work Hours program, leading to the result that the total eligible for Work Hours programs can exceed 100%. To prevent against the number of people actually participating in these programs exceeding this logical limit, the final calculated participation is determined by normalizing the eligible percent to an assumed maximum participation of 100%. An example of this procedure and illustration is provided in Section 5, along with presentation of the look-up table values and underlying assumptions.

Analysis of Travel Time and Cost Strategies Using Logit Pivot-Point Procedure - A certain class of travel demand models, known as "logit" models, provides relationships that can be tapped for this complex analysis. These models are rooted in economic utility theory, and assume that the attributes that comprise each travel option carry a certain amount of utility, or value, to the customer. If the attributes for each alternative were rolled up into a single measure of utility for each alternative, the theory holds that the consumer will choose the alternative that provides the greatest overall utility. In the case of travel mode choice, where the attributes of importance to the customer are the mode's time and cost, the traveler would be expected to select the mode that <u>minimizes</u> his/her time and cost. Higher values of time and cost are undesirable, and may be viewed as a "disutility"; hence, the choice process becomes one of *minimizing disutility*, rather than *maximizing utility*. This distinction is mainly a matter of semantics, in order to be consistent with the terminology that will be used to explain the model.

Logit models do a remarkably good job of predicting what mode an individual traveler will choose from a set of alternatives or, when applied in a regional context, what choices an entire population will make on a proportional basis from an array of alternatives. When applied for a population, the model estimates not a single preferred mode, but the percentage of travelers who will choose each of the offered modes, resulting in an estimate of modal split.

The mathematics behind the logit model may seem complicated, but the principal by which it works is not too hard to grasp. The model computes the probability (a number between 0% and 100%) that Mode *A* will be chosen when it is compared to its competing alternatives, Modes *B, C,* and *D*. It does this by first calculating the utility (disutility, actually) of each alternative, or **U**, for a given trip. A typical utility expression might look like this:

$$\mathbf{U} \,(\text{Mode } A) = \alpha_0 + \alpha_1 \,(\text{In-Vehicle Travel Time}) + \alpha_2 \,(\text{Walk/Wait Time}) + \alpha_3 \,(\text{Cost})$$

The utility of Mode *A* is a weighted sum of the travel time and cost incurred in using Mode A for the given trip. The "weights" are provided by the model coefficients, which are the α_0, α_1, α_2, and α_3 terms in the utility equation above. The coefficients relate the sensitivity of the traveler to the particular characteristic, i.e., signifying how important it will be in the choice process. The values of the coefficients are determined through a statistical estimating procedure (known as maximum likelihood estimation) applied to data from local travel surveys. Once the coefficients have been determined, the calculation of the probability of Mode A (or any of the other modes) being chosen is computed as:

$$P(\text{Mode } A) = \frac{e^{\text{Utility Mode A}}}{e^{\text{Utility Mode A}} + e^{\text{Utility Mode B}} + e^{\text{Utility Mode C}} + e^{\text{Utility Mode D}}}$$

Figure 2-4
Logit Relationship
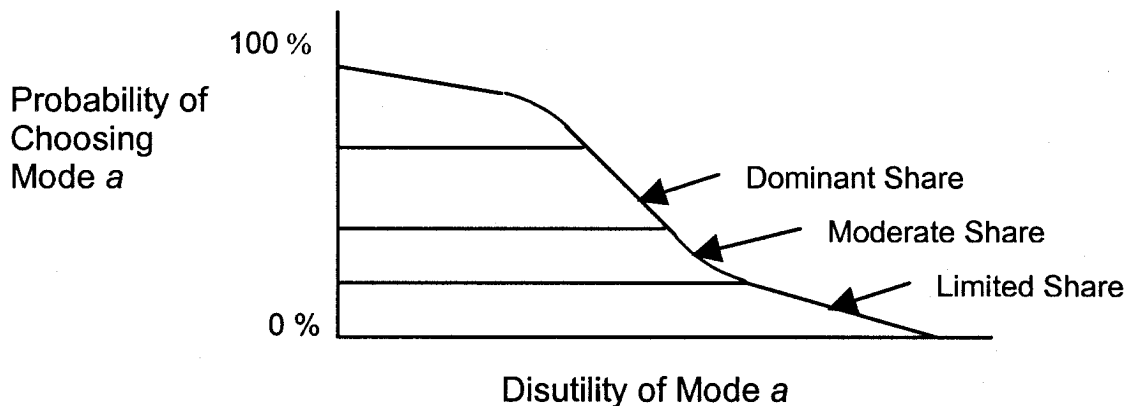
To use the logit model to analyze the effect of any policy or program, it is necessary to change the utility expression for each affected mode by relating the time or cost change from the strategy policy to each individual travel unit in the analysis. If the travel universe is an individual employer, the unit of analysis is the individual. If the universe is a region or subarea, the unit of analysis would be each of the individual origin-destination pairs that is influenced by the policy.

Because of the exponential form of the logit equation, the mode choice predictions from a logit model produce an S-shaped curve, as illustrated in Figure 2-4.

This relationship is clearly non-linear, and as the figure implies, identical changes in the travel characteristics of a given mode will not produce the same degree of change in

mode share in all cases, but will depend greatly on <u>where</u> the traveler is "starting" on the S-shaped curve. In cases where the starting share is limited, say 1% to 3%, an improvement of X minutes of travel time or Y dollars of travel cost would not produce as large an increase in share as would occur if the mode were starting with a moderate share, say 5% to 10%; a starting point in the dominant range, say 30% to 60%, would produce the most substantial changes. Above a certain mode share the mode is so dominant (so free of competition) that additional improvements in service or cost will start resulting in modest or decreasing returns. The implications of this relationship are important: if a VMEP program is to be sited in an area where existing transit or carpool use is high, then VMEP strategies that provide additional advantages to those modes should result in healthy increases. However, if a VMEP program is to be cited in an area where solo driving is dominant and there is little or no transit or carpool use, significant enhancements and incentives would be required to obtain the same shifts of travelers to transit or carpool.

While logit mode choice models are powerful and accurate, traditional application at an individual origin-destination pair level would require significant data development effort for every scenario tested. However, the tool can also be applied with reasonable accuracy to the existing mode shares, by setting up the model to predict instead the <u>change</u> in utility that would result from the <u>change</u> in the individual attributes:

$$\Delta\, U\, (\text{Mode } A)\; = \Delta\, \alpha_1\, (\text{ In-Vehicle Travel Time}) + \Delta\, \alpha_2\, (\text{Walk/Wait Time}) + \Delta\, \alpha_3\, (\text{Cost})$$

Instead of having to develop revised utility expressions for every mode and every analysis unit, the analysis can merely "pivot" from the existing share by knowing the value of the coefficients and the degree of change that will be introduced by the individual strategy or program. Moreover, in this equation, more than one service variable can be changed at a time (e.g., walk time and cost), and more than one mode can be affected at a time, and the choice probabilities for all modes may be calculated simply by making the appropriate modifications to each mode's utility expression. This feature promises a realistic accounting for the competition among modes, and reflects the gain/loss of different strategies applied in different measures to several modes.

In the COMMUTER model, the logit pivot-point procedure is used only to calculate the impacts from the Travel Time Improvements or Travel Cost Changes strategies. The application of logit pivot point to these strategies in the model is discussed in detail in Section 6 of the Manual.

<u>Sequencing Order of Calculations in the COMMUTER Model</u> - The order in which the COMMUTER model performs its calculations of travel changes is as follows:

1. It first calculates the changes due to Alternative Work Hours. This serves to readjust the travel population baseline to determine how many trips will be shifted to the off-peak, and how many will remain in the peak period and be subjected to application and analysis of the mode-choice oriented VMEP strategies.

2. Next, mode shares of the remaining peak trips are readjusted to reflect the effects of the Employer TDM Support strategies.

3. All time and cost related strategies are tallied up and brought into the logit pivot-point procedure, which is then applied to the revised mode share starting point from step 2.

Emissions Calculations

Separate calculations are performed for each of the two activity parameters modeled: VMT and trips. Emission reductions from each of these travel impacts are then added together to produce combined emission reduction impacts from changes in travel due to the TCMs evaluated. Each of these calculations is performed for both the peak and off-peak periods.

First, reductions in VMT and vehicle trips due to the TCM strategies are computed by subtracting existing activity levels from the "final" (after-TCM) activity levels.

Second, the regional speed inputs were used to linearly interpolate the stabilized emission factors by speed increment to represent these specific speeds.

Third, the number of existing and final vehicle trips were multiplied by the cold start percentages under existing and final conditions to estimate the number of cold trips for which to apply the cold start offset.

Finally, the VMT- and trip-based emission reductions were summed together. Daily reductions were also summed from peak and off-peak reductions.

Model Outputs

Key outputs include the following:

- Baseline and final mode shares for each mode, including percent of trips eliminated;

- Percent of trips shifted from the peak to off-peak period;

- Baseline and final peak, off-peak and daily VMT;

- Baseline and final peak, off-peak and daily vehicle trips; and

- Changes in total daily emissions for each criteria pollutant (HC, CO, and NOx).

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3. Assembling Required Background Information

Overview

Types of Data Required - An analysis of commuter choice strategies using the COMMUTER model requires certain basic information in order to establish the travel baseline and to properly initialize some key parameters that are used in the analysis. This section of the report lists each of the required items and explains why it is needed and how it is important to the analysis. Items included in this list and discussed in this section include the following:

- Metropolitan Area Size
- Application Setting Characteristics
- Affected Employment
- Mode Choice Model Coefficients
- Starting Mode Shares
- Average Trip Lengths
- Vehicle Occupancy
- Peak and Off-Peak Travel Characteristics

The discussion of input data requirements in this Procedures Manual focuses mainly on confirming what information is required and optional ways to supply that information, in relation to the methods being applied by the COMMUTER model. The accompanying **Users' Manual** offers the procedural step-by-step guidance to the user on where to find this information, how to format it properly, and how to enter it into the COMMUTER Model.

Areawide vs. Individual User - The COMMUTER model has been designed for application at either a regional (multi-employer) level or for an individual employment site. While the types of strategies that might be evaluated for these two applications are roughly the same, the input data requirements are somewhat different. Since an application at a regional or areawide level requires an integration of results over a large number of employers, it is necessary to have information that describes the size, composition, and travel characteristics of that population. For an individual employer, the regional composition characteristics are not relevant, and it becomes more important to be able to describe in some detail how that particular set of employees is traveling.

Therefore, regional (or multi-employer) users of the model would be expected to provide information that describes the corresponding employment base, and certain assumptions about applicability of particular strategies to these employers, or the extent to which these strategies are already in place. Much of this information will be derived from the region's or local area's transportation planning process, which is the same process that is used to prepare the SIP or to test transportation plans for conformity with the SIP. Since regional COMMUTER users would likely be the designated MPO, access to the appropriate information should be fairly straightforward. For others who might conduct VMEP analysis at either a regional or areawide level, such as departments of transportation, municipalities, counties, employer organizations, or air agencies, it is expected that these groups would need to work with the regional MPO to obtain this information and ensure its proper interpretation.

Those users performing VMEP analysis at an individual employment site will not require most of the compositional or travel information needed for the areawide analysis, but will require some fairly specific information on their individual case. Primarily, the individual site users will need information on the travel characteristics of the respective employees. This includes the following:

- Total employees working at the given site;
- Total traveling to the site on a given workday;
- Mode choice (percent by mode);
- Number traveling to the site during peak period;
- Number engaged in telework, compressed work weeks, or other alternative work schedules; and
- Existence of staggered work hours or shifts, and percent of employees accounted for in each.

This information is generally obtained through employee travel surveys, so the individual site user will not need to be concerned with regional transportation data, models and planning procedures. Guidelines are provided in the COMMUTER model and the Users' Guide to help users determine what data they need, how to obtain it, and how to use it. Default values are provided for relationships or data inputs that might not be readily available. However, even though the COMMUTER model gives the user a considerable degree of independence and flexibility, an individual site user is still strongly urged to consult with the relevant local planning agency, for the purpose of answering questions about assembly of input data, assumptions about background conditions, advice on selection of program strategies to be tested, or interpretation of results. In particular, employers should consult their planning agencies to obtain or confirm the model coefficients that will be used in the analysis (see Section 6 for more discussion on these coefficients).

Where differences occur in the data requirements or responsibilities between regional vs. individual users, the Procedures Manual and the Users' Manual will point out these differences and explain how each user should proceed.

Default Values - While most of the input data items that are requested by the COMMUTER model should be relatively easy to obtain, the COMMUTER model also provides default values for many of the items. These default values have been provided mainly as a convenience to the user, to encourage use of the model by a broad audience whose familiarity with transportation issues or access to certain data may be limited. The defaults may also be of service in performing reasonableness checks of any user-supplied data.

While these default values are provided to help the user conduct an analysis without undue difficulty or expense in obtaining local data, users are nevertheless urged to seek out and utilize current local information wherever possible. This will increase the validity of the resulting travel and emissions impacts, and help EPA reach a favorable determination when reviewing the applicant's request for COMMUTER emissions credits. Those measures for which default values are provided are listed in Table 3-1. This listing shows the default values currently assigned to each measure, and the source of the information used to develop the default value.

Users may wish to experiment with the COMMUTER using the default values in order to develop familiarity with its operation and the types of impacts it projects for various types of VMEP programs. However, programs submitted for air quality credit should give evidence of due effort to utilize local data wherever possible.

Sources for Background Data - For regional or areawide application of the COMMUTER model, most of the necessary background data should be available to or through the responsible transportation planning agency in the area. This will normally be the regional MPO, although county or municipal planning agencies or departments of transportation may also be a resource depending on the extent of their planning activity. These organizations should be capable of supplying information on regional employment, modal split, VMT and travel speeds, such as are required by the model. For individual site users, most of the background information will be obtained through an employee travel survey.

Required Model Inputs

The remainder of this section is devoted to identifying each of the required data items and providing information on typical sources. The availability of defaults for each item is noted. In addition, a glossary of transportation planning terms is provided in Appendix A to clarify the meaning of any terminology that the user may not be familiar with.

Metropolitan Area Population Size Category - The COMMUTER model distinguishes among three size categories of metropolitan area when evaluating certain impacts:

- Large: Population of 2 million or more
- Medium: Population under 2 million but $\geq$ 750,000.
- Small: Population under 750,000.

Table 3-1		
Default Values Provided in the COMMUTER Model		
Data Item	Suggested Default	Source
Work Trip Mode Shares	Auto – Drive Alone 75.4% Auto – Carpool 13.2% Vanpool 0.5% Transit 5.3% Bicycle 0.4% Walk 4.0% Other 1.1% Total 100.0%	1995 Nationwide Personal Transportation Survey (NPTS)
Average Commute Trip Length (in miles)	Average Person Trip-Length: 11.4 Average Trip Length – Vanpool: 17.7 Average Trip Length – Bicycle: 1.8 Average Trip Length – Walk: 1.0	1995 Nationwide Personal Transportation Survey (NPTS)
Average Vehicle Occupancy (persons per vehicle)	Average Carpool Occupancy: 2.2 Average Vanpool Occupancy: 6.0	1990 Census Transportation Planning Package Journey-to-Work
Duration of Peak Period	3.0 hours	
Percent of Work Trips Occurring in Peak Period	61.4% 33.8% in 6 – 9 A.M peak 27.6% in 4 – 7 P.M. peak	1990 NPTS Databook, Table 6-32
Average Travel Speeds (mph)	<u>Area Size</u> <u>Peak</u> <u>Off-Peak</u> Large 31.8 37.1 Medium 34.6 39.7 Small 34.8 39.7	1995 Highway Performance Monitoring System (HPMS)
Affected Employment	*Distribution % only, user must supply total* Office occupations: 79.7% Non-Office occupations: 20.3%	1997 Statistical Abstract of U.S., Table No. 660

The primary use of this information is to select appropriate default coefficients for use in the logit mode choice pivot point model, which is used for evaluating time or cost-based

strategies. However, since users will generally be expected to select and use the unique coefficients that have been specifically developed for their own region, and used in the officially sanctioned regional planning process, this information item is mainly for default situations only. This guidance on coefficient use is covered explicitly in Section 6.

Analysis Scope - This information item indicates to the COMMUTER model whether the analysis is to be performed at a regional or site-specific level. This selection by the user signals the modeling procedure to expect input data and specification of strategies to correspond to a single employment site or a regional population of employers. This affects what strategies are eligible, the data required of the user, and the calculation of the results.

Analysis Area Type - The COMMUTER model has a "placeholder" for this input, but does not currently use it in the travel impact calculations. If this input were active, it would work as follows. For certain types of applications, the model would need to know the "type" of area in which the program would be sited, with the options being:

- Central business district (CBD) or radial corridor;
- High density activity center or suburban CBD (other than the regional CBD); or
- Suburban, low-density area.

This information is important because VMEP programs sited in these three different types of areas are likely to have very different impacts in response to the same strategies, and as a result, certain strategies may be more effective in one environment than another. In regional CBDs or travel corridors into those areas, conditions generally favor transit and carpool use, and so existing mode shares for transit and carpool are probably the highest in the region. In contrast, suburban low-density areas typically show great reliance on private vehicle travel, while suburban downtowns or major activity centers fall somewhere in between. This distinction is important since the COMMUTER model's pivot-point procedures calculate changes in behavior based on *what was there before*. This was discussed briefly in Section 2 in the modeling discussion.

In most cases, supplying this information to the model will not be necessary for it to correctly compute its results. This is because the travel input data will generally inform the model of what the starting mode shares are. If the user is an individual site, the employee travel survey data will contain the correct starting mode shares; if the analysis is for the overall region, the work trip mode split from the regional transportation planning process will provide the appropriate starting point. Where this item may become important is if an analysis were being done for a subarea or municipality involving multiple employers, where the total employment was known but the modal shares were not. In this instance, the use of this parameter would instruct the model to provide appropriate default mode shares for this type of environment as represented by

similar sites in a national sample.[*] This is discussed in more detail under "starting mode shares" below.

When representative default mode shares by area type can be developed in a future version of the COMMUTER model, this input will be activated as described above.

Affected Employment Base - For regional (or any other areawide or multi-employer) analyses of VMEP strategies, it is necessary to describe the employment base that will be subject to the VMEP program.   The COMMUTER model requires the following information:

- The total number of employees in the employment base to which the program actions will be applied, referred to as affected employment; and

- The proportion in occupations defined as "Office" or "Non-Office" functions.

The total number of employees establishes the size of the traveling population under study, and is used to calculate baseline vehicle trips, VMT, and emissions. This number may constitute the entire regional employment population, or it may be only a portion of that population based on locally established rules of eligibility.   For example, it might be assumed that employers below a certain size would not be expected (or encouraged) to participate in voluntary commuter choice programs. For example, nationally 38% of all employees work for employers with fewer than 50 total employees, and a total of 49% work for employers with fewer than 100 employees.[**] Therefore, some users may wish to restrict assumptions on program coverage to only employers of 50 or more or 100 or more. Others may wish to restrict applicability to only those workers who travel to a work site during peak travel hours (6 to 9 a.m., and 4 to 7 p.m.); nationally, only 61.4% of workers travel during these hours, with 38.6% traveling at some other time.[***]

The calculation of impacts also takes into account differences between workers employed in "Office" vs. "Non-Office" occupations. Generally, research on TDM program effectiveness has shown that many strategies are more relevant and have greater impact in "Office" occupations, consisting of clerical, professional and managerial fields, than in "Non-Office," consisting of sales and manufacturing occupations. The FHWA TDM model, from which this procedure was adopted, defines Office and Non-Office through SIC (standard industry classification) codes, as shown in Table 3-2.

Based on this information, the model provides default percentage of 79.7% and 20.3% to help the user partition total local employment into office and non-office categories.

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[*] 1990 Census Transportation Planning Package journey-to-work statistics.

[**] U.S. Bureau of Labor Statistics, *Monthly Labor Review*, November 1996.

[***] 1977 Statistical Abstract of the United States, Table 662.

Table 3-2				
Definition of Office and Non-Office Employment				
Type	SIC Code	Industry	1996 Employment	Percent
Office	40-49	Transportation & Public Utilities	6,316,000	5.3%
	50-59	Wholesale Trade	6,587,000	5.5%
	50-59	Retail Trade	21,597,000	18.1%
	60-69	Finance, Insurance, Real Estate	6,977,000	5.8%
	70-89	Services	34,359,000	28.9%
	90-99	Government	19,461,000	16.3%
		Total Office	**95,296,000**	**79.7%**
Non-Office	10-14	Mining	570,000	0.5%
	15-17	Construction	5,407,000	4.5%
	24-39	Manufacturing	18,282,000	15.3%
		Total Non-Office	**24,259,000**	**20.3%**

Source: 1997 Statistical Abstract of the United States, Table 660.

An extremely important issue with regarding this input is that it does not represent total regional employment. The box below addresses this distinction.

"*Affected Employment*"

In addition to asking the regional user for information on overall employment size and distribution, the COMMUTER model also takes into account what portion of this population would be affected by a given strategy. It may be assumed that the entire regional employment base is affected by the strategy, or only some portion, based on minimum size criteria, location relative to the strategy, assumptions that the strategy is already being offered, or other factors. This input is not part of the baseline data requirement for the user, but rather is supplied on a strategy-by-strategy basis once the user begins to design scenarios for testing. Hence, it is covered in more detail in subsequent sections that deal with the respective strategy groups. However, it is mentioned here because it represents another way in which the user can delimit the employment base to which the VMEP strategies are applied, as an alternative to making these restrictions in the baseline itself.

<u>Existing Work-Trip Mode Shares</u> - The pivot-point analysis techniques used by the COMMUTER model to estimate travel changes rely on a starting set of mode shares for the employment population being analyzed. If the application is for an individual site (or small number of sites), this mode share information comes directly out of the employee travel survey data that the user must supply. If the application is for a region or similar areawide/multi-employer setting, then the starting mode shares must be for the respective population, and will probably be obtained from existing regional transportation planning information. The regional MPO is the most likely source for this information, although subarea analyses may find source data from county or municipal planning agencies, and/or existing employer travel surveys.

The VMEP model calls for the percentage of daily work trips that are made by the following modes:

- Auto – Drive Alone
- Auto – Carpool
- Vanpool
- Transit
- Bicycle
- Walk
- Other

Most major metropolitan areas will have information that can be used to calculate mode shares for home-based work travel (HBW) for at least auto driver, auto passenger, and transit. Vanpool is typically not broken out as a separate mode, nor is bicycle or walk, and so assumptions will have to be made as to baseline shares of these modes. Auto passenger may be used along with auto driver to determine carpool mode share (where carpool is not reported separately), but typically this calculation cannot reveal the share of multi-passenger trips that are vanpool. Where local information on mode shares for particular modes is not available, defaults in the model have been provided, and the user can opt to use the default shares for the absent modes and adjust the share values for the local "known" modes proportionately.

The COMMUTER model also makes an adjustment internally to account for workers who regularly work at home. This proportion averaged about 2.96% in the 1990 Census Journey to Work. It nets out this percentage from the total employment base when it calculates baseline work trips and VMT, and thereafter applies VMEP strategies only to those 97.04% of workers who travel.

The default shares provided in the model have been derived from the 1990 Census Journey-to-Work files, and adjusted to reflect the work-at-home factor described above. The default shares for a standard "regional" analysis developed in this manner are shown in Table 3-3.

Table 3-3 Default Shares for a Standard Regional Analysis		
Mode	**Reported 1990 Census Commute Choice**	**Excluding Work at Home**
Auto-Drive Alone	73.19%	75.42%
Auto-Carpool	12.84%	13.23%
Vanpool	0.52%	0.54%
Transit	5.12%	5.28%
Bicycle	0.41%	0.42%
Walk	3.90%	4.02%
Other	1.08%	1.09%
Work at Home	2.96%	
Total	100.00	100.00%
Total Excl. Work at Home	97.04%	

For individual site applications, shares for all modes of interest should be known directly from the data obtained through employer surveys. However, the defaults can be used to fill gaps as described above for the regional user.

Logit Model Coefficients - The COMMUTER model calculates changes in travel from time- or cost-based strategies through a logit mode choice model procedure. The critical elements in this procedure are the coefficients, which supply the "weights" that signify how important each choice variable is to the traveler. The model employs coefficients for In-Vehicle Travel Time, Out-of-Vehicle Travel Time (including Walk Time and Transit Wait Time), Auto Parking Cost, and Transit Fare. These coefficients are used in a metropolitan area's transportation planning model, and are developed uniquely for each area from analysis of local survey data.

The COMMUTER model provides coefficient values for the user through a look-up menu. The coefficient values for most U.S. metropolitan areas where the COMMUTER model might be used are included in the menu. When setting up to use the model, the user should designate those coefficients for their respective metropolitan area from the menu, and the model will automatically bring them into play.

For users who do not find their area listed in the menu, there are two options. The preferred option is to contact the responsible regional planning agency and obtain the

correct coefficients from the local model. The backup option is to make use of the default coefficients that have been programmed into the model. A separate set of coefficients is provided for Large, Medium and Small metropolitan areas. For users who are able to obtain coefficients from the local planning agency, but do not have values for all of the required coefficients, it is recommended that the default coefficients be used instead of the partial set of local coefficients. Substituting default coefficients for missing values, thus creating a hybrid, is discouraged since the two sources of coefficients may have been developed from very different assumptions.

Section 6 of this report presents further discussion on use of the logit coefficients, and a listing of those metropolitan areas currently included in the COMMUTER model.

<u>Average Trip Lengths</u> - The model employs information on average trip lengths for all modes when computing change in VMT. Since each travel mode has a different average trip length, the shifting of a commute trip from drive alone (or any other mode) to another mode will constitute a different VMT reduction depending on what modes are involved in the shift. The model has internally coded default values as follows:

- Auto Drive Alone: 11.8 miles (source: 1995 NPTS)
- Auto-Carpool: 12.4 miles (source: 1995 NPTS)
- Vanpool: 17.7 miles (source: estimated from 1990 Census travel times)
- Transit: 11.6 miles (source: 1995 NPTS)
- Bicycle: 1.8 miles (source: 1995 NPTS)
- Walk: 1.0 miles (estimate)
- Other: 11.6 miles (source: 1995 NPTS)

Average Person Trip Length: 11.42 miles
(calculated from mode shares and modal trip lengths)

Average Vehicle Trip Length: 11.85 miles
(calculated from drive alone, carpool, and vanpool mode shares, trip lengths and AVO)

The user is given the opportunity and is encouraged to supply local values for average vanpool, bicycle and walk trip length, as well as for overall person trip length. These data may be obtained through the regional planning agency or, for individual site applications, from respective employee travel surveys.

<u>Average Vehicle Occupancy</u> - Average vehicle occupancy is also used in calculating changes in VMT as well as vehicle trips. The model provides the following default values for Carpool and Vanpool occupancy:

Average Carpool Occupancy: 2.23 (source: 1990 Census)

Average Vanpool Occupancy: 6.00 (source: 1990 Census)

The user is given the opportunity and is encouraged to supply local values for average carpool and vanpool occupancy. These data may be obtained through the regional planning agency or, for individual site applications, from respective employee travel surveys.

Peak Period Duration - The model calculates emissions reductions based on changes in travel during both the peak and off-peak periods. Typically travel conditions are less congested in the off-peak period, resulting in higher average travel speeds and lower rates of emissions.

While the actual timing of the peak travel period may differ from area to area, the typical length of the peak period (either a.m. or p.m.) as recorded in the 1990 NPTS survey is three hours. This number is coded as a default into the model, but the user has the option to use local data and is encouraged to do so. Again, these data are obtained from the local planning agency.

Work Trips Occurring in Peak Period - While the peak period is when most workers are assumed to commute to jobs, nationally only 61.4% [*] of all work trips occur in the a.m. or p.m. peak travel periods. The remainder, 38.6%, take place in the off-peak hours, and occur under less congested off-peak travel conditions. The COMMUTER model uses this relationship to calculate commute trip emissions in both peak and off-peak periods, where emissions "rates" are different. The user is encouraged to supply the local value for this relationship, which may be obtained from the local planning agency.

Peak and Off-Peak Travel Speeds - This information is essential in calculating emissions, since the emissions factors are established through a relationship with average speed (this relationship is discussed in more detail in Section 7).

Other Background Information - In addition to the information items presented above, the user will probably need to obtain some other information in the course of doing an analysis. These items are briefly mentioned here, and discussed in more detail in the respective technical section that follows. The items include the following:

- Pre-existing offerings of the various employer TDM support strategies in the region, the level of the strategy or program offered, and the extent of the program's offering across the employment base (Section 4).

- Pre-existing offerings of and employee participation in alternative work schedule programs, including compressed work weeks, telecommuting, and flexible or staggered work hours (Section 5).

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[*] 1995 Nationwide Personal Transportation Survey.

- The number (or percentage) and characteristics of employers who will be affected by or who will be expected to participate in a given program scenario (Sections 4, 5, and 6).

- Peak and off-peak travel speeds (Section 7).

- Percentage distribution of the regional vehicle class by EPA size class (Section 7).

- Information on current emissions requirements, standards, and programs (Section 7).

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4. Estimating Travel Impacts of Commuter Choice Support Programs

Overview of Employer Support Strategies

One way in which employers can try to persuade employees to consider traveling by alternative modes, rather than driving alone, is to provide various types of support that make it easier and more attractive to use those modes. These support programs—often referred to as Commuter Choice or Travel Demand Management (TDM) programs— typically consist of measures that heighten awareness of the availability of other modes, provide information on their service or use, or generally make it easier and more attractive to the employee to consider their use.

These employer support programs generally do not include measurable time or cost incentives or disincentives. Rather, they serve to provide an improved set of conditions for the employee to use an alternative, and provide incentives that are tangible and important, but not necessarily quantifiable by the employee. They may best be seen as "catalysts" in supporting a change in behavior away from driving alone and providing an accommodating environment in which those changes can take place, but by themselves may not be capable of engineering major changes in employee travel.[*] Nevertheless, employers find these types of strategies attractive because they present little economic risk, and generally earn employee gratitude.

Many of the strategies in this category of programs are specific to the needs of the particular mode. For example, Table 4-1 lists typical support strategies that might be offered to encourage use of the respective mode.

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[*] See: *Implementing Effective Travel Demand Management Measures,* Federal Highway Administration, September 1993; or *Characteristics of Effective TDM Programs*, TCRP Project B-4 Final Report, COMSIS Corporation, May 1996.

Table 4-1 Popular Employer Support Strategies to Encourage Specific Modes of Travel	
Mode	Strategies
Carpool	Ride matching (individual employer or tie in to regional matching programs) Preferential (reserved and/or close-in) parking
Vanpool	Ride matching (individual employer or tie in to regional matching programs) Preferential (reserved and/or close-in) parking Use of company fueling or maintenance facilities Employer capital cost or insurance underwriting Startup subsidies
Transit	On-site transit information booths On-site transit pass sales Sidewalks or shelter
Bike	Bike lockers or racks Shower and changing facilities
Walk	Sidewalks or other barrier removal Showers and changing facilities

In addition to the mode-specific types of strategies listed in Table 4-1, there are actions employers can take that are almost universal in their applicability across all of the alternative modes. Examples of these strategies include the following:

- *Employee Transportation Coordinators*: Persons who are trained to provide information or advice to employees regarding use of any alternative mode, in terms of where to go for information, company policy and benefits, etc.

- *Guaranteed Ride Home*: Provision to get an employee home by alternative means if it necessary to work late or in event of a personal emergency, and the employee did not drive on that day.

- *Flexible Work Hours*: A formal or informal policy that allows employees some flexibility over the official office hours in order to meet the schedule of the chosen alternative mode.

- *Promotions*: Marketing and other methods to increase awareness of a given mode or employer incentive, or to provide prizes or awards for meeting some usage challenge.

Analytic Approach for Estimating Travel Impacts

Because most support-type strategies do not translate into changes in the time or cost of travel, it is difficult to calculate their impacts on travel in the same way as with time and cost-based strategies (Section 6). The latter are readily translated into terms that can be fed into a standard mode choice model, whose coefficients almost universally apply only to time- or cost-based criteria. While a number of attempts have been made to incorporate these support measures in traditional model structures, or to develop representative coefficient or elasticity relationships on their link with travel behavior, these efforts have not been particularly successful in developing valid mathematical relationships.[*]

For this reason, travel impacts related to support programs are estimated by the COMMUTER model in the same way they were calculated in the FHWA TDM model: through relational look-up tables. This approach associates the offering of a particular employer support measure with an incremental change in the mode share of the mode to which the program is applied. This is done separately for each of the designated alternative modes: Carpool, Vanpool, Transit, and Bicycle (the model currently does not incorporate measures for Walk). Table 4-2 lists the changes in mode share that are credited by the COMMUTER model for each mode and its respective program level.

The mode share adjustment values for support programs shown in Table 4-2 are taken from the FHWA TDM model. The authors of the TDM model obtained these adjustment values through a synthesis of empirical results from a large number of case studies. The TDM model researchers determined that three factors were particularly important in predicting the level of impact from a program of support actions:

- **Level of Program:** The significance of the program being offered in terms of the support measures themselves, the number and type of such measures combined into the program, and the level of investment reflected.

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[*] *A Survey and Analysis of Employee Response to Employer-Sponsored Trip Reduction Incentive Programs,* Final Report and Technical Appendix A, COMSIS Corp. for California Air Resources Board (contract #A932-187) and the South Coast Air Quality Management District (August 1993). This study attempted to develop statistical relationships for a wide range of employer support incentive strategies, drawing upon both extensive Reg. XV employer plan data from SCAQMD files coupled with new survey data from 43 California employers. Logit model estimation was used to determine whether statistically valid relationships existed between these measures and travel behavior. Results were a mixed success, with the time and cost-related strategies demonstrating the strongest relationships (and reasonable consistency with conventional models), while most of the non-monetary support strategies exhibited weak or implausible statistical relationships with demand. Those support strategies showing the strongest relationships were guaranteed ride home (all modes), transportation coordinators with rideshare matching (carpool and vanpool), use of company-provided vehicles (carpool and vanpool), transit information center and on-site pass sales (transit), and bike racks with lockers/showers (bike and walk).

- *Type of Employer:* A difference in effect was attributed to whether the measures were being applied in an "Office" or a "Non-Office" employment environment.

Table 4-2 Increase in Percent Using Model by Support Program Level						
		Program Level				
Program	Type of Workplace	1	2	3	4	
Carpool	Office	0.40%	1.00%	4.00%	6.00%	
	Non-Office	0.20%	0.40%	1.40%	2.00%	
Vanpool	Office	0.40%	1.00%	4.00%	6.00%	
	Non-Office	0.20%	0.40%	1.40%	2.00%	
Transit	Office	0.20%	0.50%	1.50%	2.00%	
	Non-Office	0.20%	0.50%	1.50%	2.00%	
Bicycle	Office	0.20%	0.50%	1.50%	2.00%	
	Non-Office	0.10%	0.25%	0.75%	1.00%	

Source: FHWA TDM Evaluation Model, 1993.

- *Level of Employer Participation:* On an areawide basis, the portion of the employment population that can be expected to take part in the program, and/or to offer a program of a given level

Program Level - For simplicity, employer support programs have been categorized into four different levels, ranging from Level 1, reflecting the minimum level of effort, to Level 4, representing the maximum. Each level is associated with a particular program or "package" of support actions. The identification of what measures have been assumed to make up each level is shown in Table 4-3. If an employer (or group of employers) is presumed to adopt one of these programs, i.e., a given level for a particular mode, it is assumed that the shown measures will be implemented by the employer.

Of course, not all employers would be expected to implement the same modal programs at the same levels uniformly across an entire region. As a result, the model allows for the user to assume and test different levels of participation across the employment population. Also, it would be unrealistic to assume that all employers would be "starting from scratch" in terms of existing programs. Many employers will already have been

doing one or more of these actions, and the analysis allows for identifying these pre-existing efforts and netting out their effects in order to avoid double counting of benefits.

Mode	Level	Strategies Included in Program
Table 4-3 **Composition of Modal Support Strategy Programs**		
Carpool	1	Carpool information activities (tied in with areawide matching) Quarter-time transportation coordinator
	2	*All the above, PLUS:* In-house carpool matching service and/or personalized carpool candidate get-togethers
	3	All the above, PLUS: Preferential parking (reserved, indoor, and/or close-in) Flexible work schedule policy to accommodate carpool schedules. Half-time transportation coordinator
	4	All the above, PLUS: Full-time transportation coordinator
Vanpool	1	Vanpool information activities (tied in with areawide vanpool matching and/or third party vanpool programs) Quarter-time transportation coordinator
	2	All the above, PLUS: In-house vanpool matching services and/or personalized vanpool candidate get-togethers Non-monetary vanpool development assistance Policy of flexible work schedules to accommodate vanpoolschedule

	3	All the above, PLUS:
		Vanpool development and operating assistance, including financial
		     assistance such as vanpool purchase loan guarantees,
		     consolidate purchase of insurance, and a startup subsidy.
		Supporting services such as van washing and fueling
		Half-time transportation coordinator

	4	All the above, PLUS:
		Major financial assistance for development and operations,
		     such as employer purchase of vans with favorable leaseback,
		     continuing subsidy, free maintenance, free insurance.
		Full-time transportation coordinator

Transit	1	Transit information center Quarter-time transportation coordinator
	2	All the above, PLUS: Policy of work hours flexibility to accommodate transit schedules/delays
	3	All the above, PLUS: On –site transit pass sales Half-time transportation coordinator
	4	All the above, PLUS: Guaranteed ride home Full-time transportation coordinator
	1	Provision of on-site bicycle parking (racks or lockers)
	2	All the above, PLUS: Shower and change facilities
	3	All the above, PLUS: Provision of secure bicycle parking (storage lockers or indoor storage) Development of local bike-friendly infrastructure
	4	All the above, PLUS:

		Workplace information and promotional activities	

Type of Employment - The research that developed the FHWA TDM model also concluded that the impact of support programs varied according to the type of workplace, in which it distinguished between Office and Non-Office employment. This shows up in travel responses for Office employment that are somewhat greater than the same strategy applied to Non-Office employment. The explanation for this is that Office employees are more likely to travel on a routine daily schedule to given work sites, while Non-Office workers (those in construction, mining, manufacturing, and utility occupations) are more likely to be traveling at non-peak times, or working shifts, or traveling to different locations depending on where the current job is.

Employer Participation - If the user is conducting an analysis at a regional or multi-employer level, it is necessary to account for the type of participation that is expected from the sample of employers. The user will be asked to specify the percentage of employers who will be expected to participate in each modal support program *by level of the program,* as well as the percentage that would not participate at all.

So, for example, if a scenario were created that envisioned employer support programs at level 2 for vanpool and transit, level 4 for carpool and level 3 for bicycle, the communication of this information to the COMMUTER model would resemble the following:

Percent of Employers Participating by Level of Program						
Mode	None	Level 1	Level 2	Level 3	Level 4	Total
Carpool					100%	100%
Vanpool			100%			100%
Transit			100%			100%
Bicycle				100%		100%

More typically, what might happen when a scenario is drawn up is that there would be much more variation in the types of participation expected, since programs would be expected to emphasize different modes based on, for example, employer location, or not include certain groups, for example, employers with fewer than 50 employees. To illustrate this point, the participation information communicated to the COMMUTER model might instead look like this:[*]

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[*] Some employer support programs may apply combinations of strategies that are different from those described in Table 4-2. In these cases, the analyst may either choose the program level that most closely compares to the actual program being implemented, or split the impact among programs of two or more different levels. For example, if a carpool program includes all the elements of a Level 3 program except

Percent of Employers Participating by Level of Program						
Mode	None	Level 1	Level 2	Level 3	Level 4	Total
Carpool	38%			12%	50%	100%
Vanpool	38%	42%	20%			100%
Transit	38%	12%	50%			100%
Bicycle	38%			62%		100%

This distribution suggests that 38% of all employers in the base would not be expected to implement any of the programs, and that of the remaining set, full participation at the design level (nominal levels shown in previous table) is probably unlikely, with some estimated percentage implementing programs that are probably at a level lower than the level intended. When this distribution is related to the model, the computation of the change in carpool mode share associated with this participation pattern would be as follows:

Carpool Mode Share Increase:

38% @ Level "0" = 0.38 x 0.0%
12% @ Level 3 = 0.12 x 4.0%
50% @ Level 4 = 0.50 x 6.0%

Net increase in carpool share = 0.0% + 0.48% + 3.0% = 3.48%

So with this example, the model would add 3.48% to the existing carpool share for this scenario, and similar calculations would be done for the other modes. This simple illustration assumes two conditions, however, that are not likely to occur in practice:

- The employment base is comprised entirely of Office employment; and

- Each of these programs is being implemented on a zero base, i.e., there are no pre-existing program efforts of this type in place.

With regard to employment type, the calculation would be expanded to account for the different level of impact projected in non-Office situations, as shown in Table 4-2. Thus

for flexible work schedules, the user may want to approximate this program by assigning half of the participation to Level 2 and half to Level 3.

if the baseline employment were comprised of, say 80% Office and 20% Non-Office, the calculation above would be revised as follows, yielding 3.02% as the Carpool share adjustment instead of 3.2%:

Carpool Mode Share Increase:

38% @ Level "0" = 0.38 x 0.0%
12% @ Level 3   = 0.12 x [(4.0% x 80%) + (1.4% x 20%)]
50% @ Level 4   = 0.50 x [(6.0% x 80%) + (2.0% x 20%)]

Net increase in carpool share = 0.0% + 0.42% + 2.6% = 3.02%

With regard to accounting for existing program efforts, this is done easily in a table equivalent to the one above, but instead specifying existing participation rates by level. An example is shown below.

Percent of Employers by Existing Program						
Mode	None	Level 1	Level 2	Level 3	Level 4	Total
Carpool	50%	50%					100%
Vanpool	95%	5%					100%
Transit	50%	40%	10%				100%
Bicycle	95%	5%					100%

Given this information, the COMMUTER model will compute the net impact from the new scenario of actions by subtracting out the portion of the effect that may be attributed to existing efforts. Using the Carpool example again, the share that may be attributed to existing efforts is calculated as follows:

Carpool Mode Share Increment Due to Existing Efforts:

50% @ Level "0" = 0.50 x 0.0%
50% @ Level 1   = 0.50 x [(0.4% x 80%) + (0.2% x 20%)]

Credit for Existing Program = 0.0% + 0.36% = 0.36%

The net increase that may then be attributed to the Carpool support program of the scenario, after crediting for existing efforts, is 3.02% - 0.36%, or 2.66%.

Site vs. Areawide - Users of the COMMUTER model who are evaluating employer support programs at an individual site level will find slight differences in how the model treats a single employment site vs. the more challenging simulation of these programs applied across a diverse employer population, as discussed above. The basic analytics are the same, however, employing the same mode share adjustment procedures and affording the same level of impact. The only difference is that the user does not have to specify the distribution of the programs across the employment base.

Model users are asked at the early stage of model application whether the analysis will be for an individual site or areawide. The model then automatically directs them to the individual site screen, where they are asked to enter the following information:

Program Focus	Existing Level	New Level
Carpool		
Vanpool		
Transit		
Bicycle		

As with the multi-employer case, the individual site user first enters the "Existing Level" that best corresponds to the type of program that is being offered now (from 1 to 4, with the default being Level 0), and then selects the New Level that best represents the program that will be offered. This is done individually for each mode. The model then determines the change for each mode under the New Level, and nets out the credit for the Existing Level.

The COMMUTER model also offers an alternative procedure that give the user even more flexibility to experiment with the potential impact of support programs. The following alternative table is presented in the model:

Program Focus	Existing Share	Increase	New Share
Carpool	13.2 %	%	13.2 %
Vanpool	0.5 %	%	0.5 %
Transit	5.3 %	%	5.3 %

Bicycle	0.4 %	%	0.4 %

To use this procedure, the user enters the percentage *increase* that is expected for each listed mode through the given set of program actions, and the model automatically makes the adjustment from the Existing Share to the New Share. This type of procedure is useful only if the user has previously compiled company survey data on how employees' mode shares would change if a support program were implemented. (Note that the existing shares in this input table come from the baseline mode share inputs.)

Absence of Walk Mode - While employers can make an effort to encourage those employees who have the opportunity to walk to work, the specific incentive measures are perhaps less tangible for pedestrian travel. Neither the individual site nor the areawide applications for support programs in the COMMUTER model provide for increasing walk mode share; however, the model does preserve the share that is already there, by freezing the starting share of walk trips and not including it in the normalizing process (described below) that balances the share adjustments across all the other modes. Walk mode share can be increased through improvements in walk access time to the site, as described in Section 6.

Normalizing Across Modes - Once the mode shares of each commute mode have been adjusted upward by the increment associated with the respective support program, the sum of all modal shares will almost always exceed 100%. In the logit mode split model procedure (Section 6), the total shares are constrained to 100% by virtue of the way the equation works, i.e., by dividing up the "pie" in proportion to the respective "utilities" of each mode. In this more simplistic procedure, however, where increments are added to each mode without accounting for "where" (what other mode) those new riders come from, some readjustment must be made to bring the sum of all shares back to 100%. This is done through a process called normalizing, where each mode's share is divided by the new total, proportionately reducing each share so that the total once again is 100%. This is equivalent to assuming that the increase in each mode share affected by a program will come from the other modes in proportion to their starting mode shares.
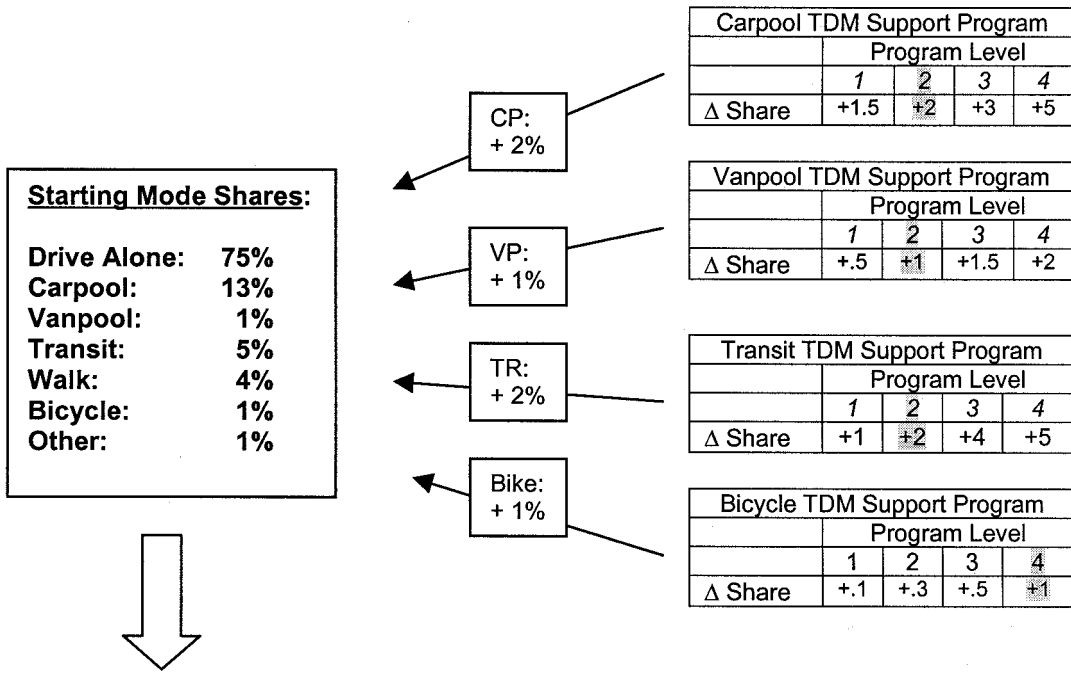
The important exception to the procedure of proportioning the adjustments across modes is that Walk is not included in the adjustment process. The normalizing process simply freezes the Walk share at its existing level, and it neither gains nor loses as a result of the support program impacts.

A simple example shown as Figure 4-1 illustrates how the normalizing process works (this example was also used earlier in Section 2). Initial shares of carpool, vanpool, transit and bicycle are increased through individual support programs. Carpool is increased from 13% to 15%, Vanpool from 1% to 2%, Transit from 5% to 7%, and Bicycle from 1% to 2%. The problem, though, is that these various programs add 6% to the targeted modes, but no mode has had to give up any users. To correct this, the 6% are "found" from among all of the other modes, including the ones that have been targeted (except Walk, which remains excluded from this process). This amounts to multiplying

each share by the ratio of the new total to the old total, or 96%/102%, or 0.941. This means that Carpool's increase from 13% to 15% is dropped back to 14.1%, Vanpool's and Bicycle's 2% dropped back to 1.9%, and Transit's 7% dropped back to 6.6%. However, in this process Drive Alone drops from 75% to 70.6%, losing the greatest share because its share was initially the largest.

Figure 4-1
Illustration of Share Adjustment Process

Starting Mode Shares:

Drive Alone:	75%
Carpool:	13%
Vanpool:	1%
Transit:	5%
Walk:	4%
Bicycle:	1%
Other:	1%

CP:
+ 2%

VP:
+ 1%

TR:
+ 2%

Bike:
+ 1%

Carpool TDM Support Program				
	Program Level			
	1	2	3	4
Δ Share	+1.5	+2	+3	+5

Vanpool TDM Support Program				
	Program Level			
	1	2	3	4
Δ Share	+.5	+1	+1.5	+2

Transit TDM Support Program				
	Program Level			
	1	2	3	4
Δ Share	+1	+2	+4	+5

Bicycle TDM Support Program				
	Program Level			
	1	2	3	4
Δ Share	+.1	+.3	+.5	+1

Share Adjustment Process:

	Base	Δ	Revised	Adjustment Factor	Final Shares
Drive Alone:	75%		75%	.941	70.6%
Carpool:	13%	+2%	15%	.941	14.1%
Vanpool:	1%	+1%	2%	.941	1.9%
Transit:	5%	+2%	7%	.941	6.6%
Walk:	(4%)		(4%)	1.0	(4%)
Bicycle:	1%	+1%	2%	.941	1.9%
Other:	1%		1%	.941	0.9%
TOTAL	96%		102%		100.0%

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5. Estimating Travel Impacts of Alternative Work Schedules

Overview of Alternative Work Schedule Programs

Rather than trying to induce a change in mode of travel, this class of commuter choice strategies is aimed at reducing the frequency of the commute trip (i.e., the number of trips made by the employee to the site per week), or shifting the timing of the trip outside of the peak hour or period. These are broadly referred to as Alternative Work Schedules or Arrangements, and consist of the following popular options:

- **Flexible Work Hours:** A relaxation in the official daily hours of business allows employees the flexibility to adjust their personal work schedules to either come early/leave early, or come late/leave late in order to avoid the most congested portion of daily commute periods.

- **Staggered Work Hours**: A more formalized version of the above, where the employer sets one or more starting/ending times within a small time increment of each other, so that all employees are not arriving/departing at the same time. For example, one half of the workforce may arrive at 8:00 a.m., and the other half at 8:30 a.m.

- **Compressed Work Weeks:** Rather than working a standard 5-day/8-hour-per-day work week, some employers will allow employees to work a longer work day, usually either 9 or 10 hours, and build credit in order to be exempt from traveling to the site on a particular day. The most common versions of compressed work week arrangements are 4/40, where the employee works four 10-hour days and then takes the fifth day off, or 9/80, where the employee works nine 9-hour days and takes the tenth day off.

- **Telecommuting:** Also sometimes referred to as "telework", this arrangement allows employees to work off-site usually one or more days per week, being in communication with the worksite via telephone or computer modem connection.

Typically an employer will offer only one of these programs to its employees, since, to a certain extent, taking part in one nullifies the ability to participate in the other. However,

there may be occasions when more than one of the programs may be offered, perhaps to a different segment of the employer's work force. The COMMUTER model estimates the impact of each of these Alternative Work Schedule programs, and permits offering more than one program at a time with some practical constraints imposed to prevent unrealistic cases of dual eligibility.

Nature of Emissions Impacts

Whereas employer commute choice programs that induce changes in travel mode lead to reductions in vehicle trips and VMT and thus fewer emissions, Alternative Work Schedule programs reduce emissions by eliminating trips or pushing them to a less congested time period. A brief description of how each of the listed programs would be expected to reduce emissions is provided below.

- **Flexible Work Hours:** Emissions reductions from flexible work hours are determined entirely by the number of vehicle trips shifted from the peak period to the non-peak period. Emissions reductions occur because congestion is less and speeds are higher in the off-peak. An important assumption with flexible work hours is that shifting work hours does not take away the incentive to use transit or ride in a carpool or vanpool, since driving alone may be more attractive outside the peak period.[*]

- **Staggered Work Hours:** Same as flexible work hours, emissions reductions from staggered hours are dependent entirely on the number of vehicle trips shifted out of the peak period. The same important assumption as to whether employees have the same incentive to use transit or rideshare applies as with flexible work hours.

- **Compressed Work Weeks:** This strategy reduces emissions by eliminating vehicle trips to the work site. 4/40 programs eliminate one out of five trips per week, while 9/80 programs eliminate one trip out of every ten, or 0.5 per week. A critical assumption in claiming emissions credits from these trips shifted is that equal or greater travel does not occur on the individual's day off.

- **Telecommuting:** This strategy also reduces emissions by eliminating vehicle trips to a work site. As with compressed work weeks, the critical assumption is that travel on the telecommute day is negligible because the employee is home working.

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[*] Flexible work hours as presented here is not to be confused with the flexible work schedule policy described in Chapter 4 as a way of encouraging alternative mode use by granting leniency to employees who need to adjust their hours to meet the schedule of a carpool/vanpool or transit.

Analytic Approach for Estimating Travel Impacts

Three factors enter into the calculation of the travel impacts from Alternative Work Schedules:

1. Which strategy or strategies are being offered?

2. What type of occupation is the target employment engaged in, i.e., is it suitable for the particular type of alternative work arrangement? The COMMUTER model calculates Alternative Work Schedule travel impacts only for Office employment.

3. What percentage of employees are made eligible for (or are expected to participate in) the programs by employers?

A fourth factor becomes important in specific relation to emissions impacts, namely, the length of the peak period as a factor in determining the number of trips that would actually be shifted outside the peak.

Like the Commuter Choice Support Strategies (Chapter 4), Alternative Work Schedule programs are also analyzed using factors supplied in lookup tables. The user enters preferences as to which strategies will be offered, and indicates the percentage of employees who will be eligible for (or, alternatively, would be expected to participate in) each. The COMMUTER model then makes a calculation that either removes vehicle trips from the total or shifts those trips to the off-peak period. Research reviews identified no elasticities or coefficients that could be used for estimating the response of travelers to these strategies. As a result, simple factor relationships taken from empirical research, in combination with some simple mathematical identities, are used to calculate the travel impacts for these strategies.

The calculation of the travel impact for each of the Alternative Work Hours programs is explained below.

Flexible Work Hours - Using relationships developed for the FHWA TDM model, the COMMUTER model assumes that in employment situations where employees are made eligible for Flexible Work Hours options, 22% will in fact take advantage of that option and participate in a program that will shift their hours of travel.[*] Alternatively, users can specify directly what percent are expected to participate, and in effect replace the 22% default with their own estimate; there should, however, be some explanation as to what information justified this assumption.

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[*] This percentage was derived from data compiled in a 1980 study "Behavioral Impacts of Flexible Work Schedules."

The user is also asked to supply information on the <u>existing</u> percent of employees eligible for (or already participating in) Flexible Work Hours. As with the Employer Support Programs (Chapter 4), the <u>net</u> ***new*** percentage of eligible (or participating) employees is used to estimate the impact.

Exactly how many of the employees who elect to participate in Flex Hours actually shift their time of travel such that the new trip falls outside the peak depends on the length of the peak period. If the peak period is short (e.g., two hours in duration), then the likelihood that a trip shifted by flexible work hours will fall *outside* the peak (and hence become associated with lower emissions rates) is fairly high, whereas with a long peak period, say 4 or more hours, only a relatively small percentage would be expected to fall outside the peak. Table 5-1 shows the shift percentages as related to length of peak period that are coded into the COMMUTER model.

Table 5-1 Percent of Trips Shifted by Length of Peak Period	
Length of Peak Period (hrs)	Percent of Trips Shifted
2.0	28.7
2.5	19.2
3.0	13.9
3.5	10.6
4.0	8.5
4.5	7.1
5.0	6.0

Source: *Estimating the Effect of Alternative Work Schedules on Travel Activity and Emissions, FHWA TDM Evaluation Model*, 1993.

The user supplies the local information on length of peak period. This item appears on the screen for Alternative Work Hours strategies as "Percent of Trips Shifted from Peak Period." The user may use the default value of 3 hours if local data are not easily available.   If local data are available on the percentage of trips shifted from the peak, they should be used in place of the defaults given in Table 5-1.

It is important to note that not all of the trips being shifted under Flexible Work Hours are <u>vehicle </u>trips. Employee trips are shifted at the same modal split as exists in the overall population; hence, if only 80% of employees drove alone, and 10% rode in 2-person

carpools, then only 85% (80% + 10%/2) of the shifted trips would be assumed to be vehicle trips.

The calculation of the travel impact from flexible work hours is then as follows:

Number Daily Vehicle Trips Shifted,
Peak to Off-peak =

Total Affected Employment
X
Percent of Employment that is Office
X
NET Percent of Employees Eligible
X
22% Participate in Program
X
Percent of Trips Shifted
(Based on Length of Peak Period)
X
Current Private Vehicle Mode Share

The following example illustrates the effect of Flexible Work Hours:

Total Vehicle Trips Shifted from Peak =

(100,000 employees) X (75% Office) X (30% – 10% eligible) X (22%) X (13.9% shifted)$^{3 \text{ hr peak}}$ X (.85 vehicle trips per employee) = 390 daily vehicle trips shifted

Alternatively, the user could specify the percent of employees that would be expected to participate in the program if offered (less the percent already participating). In the above example, if the "Eligible" percentages were in fact already "Participating," the calculation would change as follows:

(100,000 employees) X (75% Office) X **(30% – 10% participation**) X̶ ̶(̶2̶2̶%̶) X (13.9% shifted)$^{3 \text{ hr peak}}$ X (.85 vehicle trips per employee) = 1,772 daily vehicle trips shifted

This is a very different outcome, 1,772 vs. 390 trips, than when the participation is entered directly. For this reason, the user should be aware of the difference in significance between using the Percent Eligible vs. the Percent Participating option in the model, and apply caution if using the latter option.

Staggered Work Hours - The travel impacts from Staggered Work Hours are determined in exactly the same manner as Flexible Work Hours above. The user indicates [either] the percentage who will be Eligible, or who will be expected to Participate, with the same caveats as discussed above. The model then calculates the number of trips that will be shifted, and the number that will be assumed to fall outside the peak and qualify for favorable emissions treatment.

Compressed Work Weeks - Calculation of travel impacts from Compressed Work Weeks follows a very similar procedure to the one above for Flexible and Staggered Work Hours. The principal difference is that employees who opt to participate in Compressed Work Weeks are assumed to make fewer trips to the worksite, rather than the same number of trips but shifted out of the peak.

To estimate the effects from Compressed Work Weeks, the user must indicate:

- The percent of employees who will be eligible for the new program, or who will be expected to participate;

- The percent who are already eligible for (or participating in) a similar compressed work hours program; and

- Whether the program type will be a 4/40 or 9/80 arrangement (percent by each).

The COMMUTER model then calculates the number of daily vehicle trips that would be eliminated from the Compressed Work Week programs, as a function of the total number of Office (only) employees, the net new percent eligible or participating, the current modal share, and the effective daily trip reduction attributable to the type of program (4/40 or 9/80).

As with the Flexible or Staggered work hours programs, if the user specifies the percent or employees Eligible, the model will assume that 22% of these eligible employees will participate in the program. If given directly the percent who will participate, it will use 100% of this estimate.

For each employee who participates in a compressed work week program, the following trip reduction will be estimated:

4/40 Work Week: 1 trip per week or 0.20 trips per day.

9/80 Work Week: ½ trips per week, or 0.10 trips per day.

Again, as with the work hours strategies, the elimination of trips is assumed to be proportional across all current modes, i.e., they are not all vehicle trips being eliminated.

The calculation of the travel impact from Compressed Work Weeks is then as follows:

Number Daily Vehicle Trips Eliminated =

Total Affected Employment
X
Percent of Employment that is Office
X
NET Percent of Employees Eligible
X
22% Participate in Program
X
Daily Person Trips Eliminated
(0.20 for 4/40, 0.10 for 9/80)
X
Current Private Vehicle Mode Share

The following example illustrates the effect of Compressed Work Weeks (based on eligibility):

Total Vehicle Trips Eliminated =

(100,000 employees) X (75% Office) X (30% – 10% eligible) X (22%) X (0.20 trips)$^{4/40 \text{ Week}}$ X (.85 vehicle trips per employee) = 561 daily vehicle trips removed

Alternatively, the user could specify the percent of employees that would be expected to participate in the program if offered (less the percent already participating). In the above example, if the "Eligible" percentages were in fact already "Participating," the calculation would change as follows:

(100,000 employees) X (75% Office) X **(30% – 10% participation**) X (22%) X (0.20 trips)$^{4/40 \text{ Week}}$ X (.85 vehicle trips per employee) = 2,550 daily vehicle trips removed

This is a very different outcome, 2,550 vs. 561 trips, compared to when the participation is entered directly. For this reason, the user should be aware of the difference in

significance between using the Percent Eligible vs. the Percent Participating option in the model, and apply caution if using the latter option.

The user should also apply caution in interpreting the trip reduction number, given uncertainty as to the travel behavior of the employee on the "day off."

Telecommuting - Calculating the travel impacts from Telecommuting is slightly different from both prior classes of strategies, but similar to the Compressed Work Week in that impacts are registered as trips eliminated as opposed to trips shifted from peak to off-peak.

To estimate the effects from Telecommuting, the user must indicate the following:

- The percent of employees who will be eligible for the new program, or who will be expected to participate;

- The percent who are already eligible for (or participating in) a similar Telecommuting program; and

- The average number of days per week that employees will telecommute, i.e., work at home, if different from the 1.8 day default value coded into the model.

The COMMUTER model then calculates the number of daily vehicle trips that would be eliminated due to Telecommuting as a function of the total number of Office (only) employees, the net new percent eligible or participating, the current modal share, and the average number of days per week that the employee will work at home under the telecommute arrangement.

As with the Flexible/Staggered work hours or Compressed Work Week programs, the user may either specify the percent of employees who will be eligible for a Telecommute program, or the exact percentage that will participate. If the user opts for the "Eligible" approach, the model will assume that **32%** of the eligible employees will participate in the program.[*] If the percent who will participate is provided directly, the model will use 100% of that estimate.

For each employee who participates in a Telecommute program, the following trip reduction will be estimated:

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[*] The study "Telecommuting in the United States," reported in the ITE Journal in December 1992, presented data from a national survey that indicated that if given a chance to Telecommute, about 32% of employees would participate and telecommute on a *given day*. The same study also indicated that of those employees who did participate in a telecommute program, the average number of days per week that they would work at home was 1.8 days.

1.8 days per week work at home / 5 days per week = 0.36 trips per day eliminated. (user has option of changing the 1.8 day default)

Again, as with the other strategies, the eliminated trips are assumed to be proportional across all current modes, i.e., they are not all vehicle trips being eliminated.

The calculation of the travel impact from Telecommuting is then as follows:

Number Daily Vehicle Trips Eliminated =

Total Affected Employment
X
Percent of Employment that is Office
X
NET Percent of Employees Eligible
X
32% Participate in Program
X
Daily Person Trips Eliminated
(0.36 based on 1.8 days)
X
Current Private Vehicle Mode Share

The following example illustrates the effect of Telecommuting (based on eligibility):

Total Vehicle Trips Eliminated =

(100,000 employees) X (75% Office) X (30% – 10% eligible) X (32%) X (0.36 trips)$^{1.8 \text{ days/week}}$ X (.85 vehicle trips per employee) = 1,469 daily vehicle trips removed

Alternatively, the user could specify the percent of employees that would be expected to participate in the program if offered (less the percent already participating). In the above example, if the "Eligible" percentages were in fact already "Participating," the calculation would change as follows:

(100,000 employees) X (75% Office) X **(30% – 10% participation**.) ~~X (32%)~~ X (0.36 trips)$^{1.8 \text{ days/week}}$ X (.85 vehicle trips per employee) = 4,590 daily vehicle trips removed

This is a very different outcome, 4,590 vs. 1,469 trips, compared to that obtained when the participation is entered directly. For this reason, the user should be aware of the significant difference between using the Percent Eligible vs. the Percent Participating option in the model, and apply caution if using the latter option. The user should also apply caution in interpreting the trip reduction number, given uncertainty as to the travel behavior of the employee on the "day off."

Multiple Options

The COMMUTER model permits the user to examine a program scenario with more than one of the alternative work hours strategies at one time. If the analysis is being done at a regional scale over many employers, it is practical to assume that more than one option would be tested in the same scenario. Generally, the user is advised to limit the total eligibility—or participation—in all programs to 100% of the affected employment base. When the model is asked to estimate the effects of multiple programs in the same scenario, it simply calculates the program effect for each program, e.g., Flexible Work Hours, individually, and then simply adds the results to a grand total of "number of trips shifted to off-peak" and "number of daily trips eliminated." Unlike the Employer Support Strategies of Chapter 4, however, because the user is advised to limit total participation to 100%, there is no concern about one program competing for share with the other and necessitating a tradeoff and normalizing process.

Even an individual employer using the model might opt to make more than one Alternative Work Schedules strategy available, and so long as the total eligibility or participation does not exceed 100% of all employees, no reconciliation of shares across programs is necessary in the model.

However, one could envision the scenario where an employee might be eligible for more than one program option, or in fact be eligible for any of the options simultaneously. In this instance, the employee might choose to participate in more than one program, limited only by the interference that might occur between one program and another. For example, an employee "eligible" for Compressed Work Weeks, Flexible Work Hours, and Telecommuting might find it difficult in practice to be able to take advantage of more than one of these options. If the employee is on a 4/40 work week, for instance, it is difficult to see how they could also telecommute, or participate in a Flexible Work Hours program. Nevertheless, to accommodate this real possibility, the model allows the user to specify more than 100% eligibility or participation across all programs, in essence letting the employee "decide" which program or combination of programs to take part in. To deal with this in the model calculations, each program's share is first computed individually, as before, assuming that the employee has only one option available.

However, once all the individual choices are computed, the sum of the eligibility or participation rates is computed, and if in excess of 100%, the computed effects of each program is normalized back to an effective participation of 100%. This gives a very liberal opportunity to the user to test broad strategies, while still adhering to basic reasonableness criteria regarding use of more than one alternative at a time.

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6. Estimating Travel Impacts of Travel Time and Cost Changes

Overview of Travel Time and Travel Cost Strategies

Perhaps more than any other type of strategy, those measures that change the time or cost of making a trip seem to have the most significant impact on travel behavior.[*] As a simple example, if a traveler had two alternatives for making a trip, A and B, which the traveler saw as basically equal options, reducing the travel time or the travel cost associated with alternative B would make B more attractive, and the traveler more likely to choose that alternative. Exactly how much more attractive it would be depends on how big the relative changes are, which components of time or cost are changed (since they are weighted differently by the traveler), and other intangibles such as the purpose of the trip, the occupation and income of the traveler, and so forth.

Travel time and cost are also the most measurable elements of transportation choice. Whereas it may be difficult to precisely measure the value of, for example, a guaranteed ride home program as an employer incentive to encourage transit or ridesharing, incentives that involve changes to travel time or cost are quite measurable. As a result, statistical analysis of travel behavior shows a strong and consistent relationship between travel choice and the level of time and cost associated with the trip.

The economic framework upon which travel demand analysis and forecasting is based suggests that travelers view travel as a means of accomplishing a need, and consider several factors when deciding whether and how to make a trip:

- Trip Purpose: Depending on the type of activity to be satisfied, the need to make a trip may be less flexible for some purposes than others. Travel to work, for example, is generally less negotiable than making a social or recreational trip.

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[*] See for example: Federal Highway Administration. *Implementing Effective Travel Demand Management Measures.* (1993), and Transit Cooperative Research Program. *Cost Effectiveness of TDM Strategies.* TCRP Project B-4 (1995).

- Trip Frequency: In addition to deciding whether to make the trip, the traveler also has the choice, depending on the purpose of the trip, of how often (daily, less than daily, etc.) the trip will be made.

- Destination: When the traveler is not committed to a single site for satisfying the activity, as is generally the case with the commute trip, more than one location may be acceptable.

- Travel Mode: The traveler may have more than one travel mode to choose from, e.g., driving, walking, taking transit, depending on the coordinates of the trip and what modes are available.

- Time of Day: Again, depending on the purpose of the trip and the flexibility of the schedule, the traveler may adjust the hour of the day that the trip is made in order, for example, to avoid traffic congestion that will make the trip take longer.

In the case of travel made for the purpose of work, many of the traveler's options are limited: generally the trip must be made on a daily basis, to a fixed destination, and at a given time of day. The Alternative Work Schedule strategies presented in the previous chapter have introduced some flexibility into this set of choices, allowing some travelers some discretion over how often they travel from home to the worksite, or at what times of day.

Generally, however, the principal choice to the commuter is in what *mode of travel* to use. Except for those persons whose households do not own vehicles, the most commonly used alternative is driving alone. Principal alternatives that represent choices to driving alone are carpooling, riding transit, or joining a vanpool. Persons whose residence is reasonably close to the work place may also have the choice of walking or biking.

When evaluating these modal choices, the consumer is believed to look at how long it will take and how much it will cost to travel from door-to-door, as depicted in the figure below.
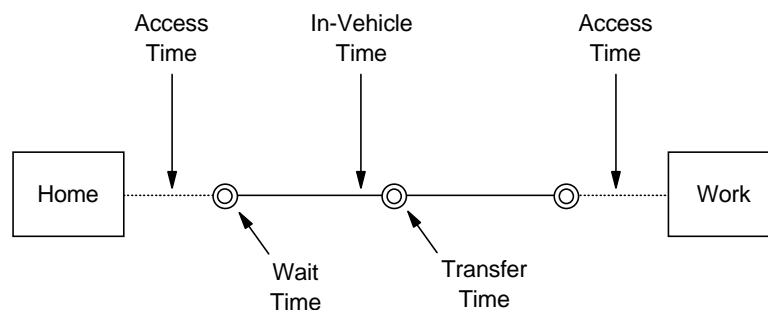
In other words, the comparison among the options is based on how much time and effort is involved in getting from the home to the mode of travel (access time), traveling in that mode to the destination (in-vehicle time), and then getting from the point of debarking to the final destination (access time). For most travelers, driving a personal vehicle represents the most convenient solution to this comparison. The auto user walks to the parked vehicle (usually in a driveway or garage), drives directly to the workplace, and parks within fairly short walking distance of the workplace. For the great majority of American workers, the auto user is also likely to find ample free or subsidized parking at the worksite.

In contrast to the option of driving alone, which is virtually "door-to-door", each other mode involves some type of compromise. The carpool or vanpool user must give up some flexibility of arrival and departure time to accommodate the schedule of the other riders, and often spend a bit more time traveling just to connect up with the other pool users (access or in-vehicle time). The transit user must first get to the transit line, either by walking or driving, then wait for the transit vehicle to arrive (wait time), and then walk from the transit stop at the end of the trip to the final destination. In some instances, it is also necessary to use more than one transit service, involving a transfer and potential wait (transfer time). Persons who would walk or bike to work face not only limitations on "reasonable distance" (generally 1 mile for walk, about 2 miles for bicycle), and exposure to weather and traffic, but also physical barriers that make access to the site difficult and add time.

What makes transit, ridesharing, biking, or walking attractive to some travelers, other than matters of pure personal preference or constraint, are time or cost advantages of one mode over the other. If users of carpools, vanpools, or transit can gain a travel time advantage over the single-occupant vehicle by having a separate facility that avoids congestion, that can alter the balance. Changes at the destination end that reduce the time and difficulty of reaching the site are also important. For transit users this might mean a stop closer to the building or a more direct path of access to the building. For carpool or vanpool users this might mean close-in preferential parking. For bikers or pedestrians, it might mean improved access to the site that reduces the time and distance.

Travel cost can also be a factor that tips the balance toward one of the alternative modes. The typical SOV user usually only recognizes the cost of operation of the vehicle. Tolls and parking fees are clearly noted, but are seldom in place, so the SOV traveler sees their mode as very cost-effective. Transit users, on the other hand, must pay a fare that is no longer a "nominal" charge in most urban systems. Vanpool users usually pay a monthly or weekly charge, and carpoolers split their costs to where it is less than driving alone, but if the trip does not involve parking, tolls or other out-of-pocket fees, the savings may not be significant. Obviously, bikers and pedestrians have the cheapest alternative, trading their time and effort for avoidance of monetary cost.

Actions that can make transit, ridesharing, or biking/walking more attractive to potential users from a cost point of view would entail either increasing the cost of driving alone or decreasing the cost of using the alternative. Fare subsidies are the most common cost incentive for transit users. Employers have also been known to subsidize or underwrite the costs of vanpooling, and there have been instances of employers providing "equipment" subsidies to encourage biking or walking.

Perhaps the most significant incentive to the decision to drive or not drive, however, is the cost of parking. Since most employers offer free or subsidized parking to employees, this substantial benefit is a major subsidy to employees who drive. Where employers have imposed charges on parking, major differences in drive alone mode share can be observed.[*] There are many variations on this theme of using parking cost as a transportation demand management incentive, including the following:

- Combining parking fees for SOVs with free or subsidized parking for carpools or vanpools.

- Offering a "Cash-Out" payment in the amount of the employer's cost to provide parking to the employee as an incentive to not drive alone.

- Taking the revenues from employee parking fees and distributing them back to employees as targeted or general subsidies to support use of other modes.

Types of Time/Cost Strategies Covered by COMMUTER Model

The COMMUTER model is fairly flexible in its ability to look at a variety of travel time or travel cost incentive strategies. These strategies can be targeted at individual modes, and numerous strategies can be included within the same scenario. The model will deal with the interactions among the modes under the influence of the selected package of strategies through a multinomial logit modeling procedure, described in the next section.

Site Access Improvements - The user can test strategies that change the current time required to access the employment site once it is reached by the respective mode. This can be done for any or all of the modes at the same time, with different assumptions for each mode. Testing a negative value of change in access time (e.g., -two minutes) constitutes an incentive since it reduces travel time, while testing a positive value represents a disincentive for that particular mode.

Changes in walk access time for carpools, vanpools, or drive alone can be realized through parking supply management techniques, such as preferential close-in parking for

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* See again: FHWA *Implementing Effective Travel Demand Management Measures* (1993) and TCRP B-4: *Cost-Effectiveness of TDM Strategies* (1995).

pools or on-site vs. off-site parking privileges. Changes in access time for transit, biking, or walking can be realized through improved site access design, affording a more direct and safe connection to the transit stop or the local community or sidewalk/street network.

Transit Service Improvements - Most employers are not likely to *initiate* strategies that will change the travel time associated with transit service, other than the improvements to on-site access described above. However, users examining regional applications of the COMMUTER model may envision and wish to test the consequences of improving the travel time associated with improved transit service.

Transit service can provide shorter door-to-door travel time as a result of the following changes:

- Increased frequency of service (i.e., shorter headways between vehicles), which allows reduction in wait time or transfer time.

- More direct service, which could result in both reduced in-vehicle travel time as well as elimination of transfer time.

- Faster service, which could result from introduction of express type service, more direct service, or operation on an exclusive facility/right-of-way that is free of highway traffic congestion.

COMMUTER model users can incorporate improved transit service in their scenarios by making changes in either Frequency of Service (which is analyzed as "wait time") or Faster Service (which is analyzed as "in vehicle time"). Improvements in ease of accessing transit—even if they occur off-site—can be evaluated through the Access Time feature described above.

Changes in Parking Costs - The model allows users to examine the effectiveness of imposing parking fees. These may either be changes in fees that are currently in place, or introduction of fees where parking is currently free. Because the user provides the model with information on how parking cost would change for *each* relevant mode—Drive Alone, Carpool, and Vanpool, it is possible to assume a different fee for each mode. Through the use of positive (+) and negative (-) entries, it is also possible to treat the change in parking fee as a surcharge (increase) or as a reduction or subsidy. For example, if a site currently imposed a $1.00 per day charge for all vehicle parking, it would be possible to test a $1.00 daily increase (+$1.00) on SOV users while keeping the fee for carpools at the present $1.00 a day and making parking for vanpools free by entering -$1.00.

When the model calculates the impact of the parking cost, or any other cost strategy, it assumes that the cost is divided evenly among the vehicle's occupants. Thus, for SOVs, a $1 daily charge increases the cost for the SOV traveler by $1, while an increase in $1 for

a 2-person carpool would increase the cost for the carpool user by only $.50, and for a 10-person vanpool by only $0.10.

Fare Cost - The cost element that is most relevant to transit use is the level of fare paid. The COMMUTER model allows the user to test the effect of reducing transit fares by entering the daily change (i.e., per round trip) in cost to the user. Entering a negative (-) value constitutes a subsidy (or cost reduction), while entering a positive (+) value constitutes a fare increase. Under certain circumstances a user might want to examine the effect on employee travel if a general fare increase was proposed by the local transit agency.

Other Financial Incentives or Disincentives - In addition to the specific parking and transit fare measures described above, employers may also utilize pricing strategies in other ways to either encourage alternative mode use or discourage SOV use. For example, some employers have imposed a cost for parking on site and then used the revenues to provide general subsidies to some or all of the alternative modes, including walk and bicycle. To permit analysis of this type of measure, the COMMUTER model has a place where the user can enter and test daily round trip cost changes—either increases or decreases—for any or all of the available modes. These strategies can be tested simultaneously with changes in parking pricing or transit fares, although the user should not apply the same strategy in both places in the same scenario.

Analytic Approach for Estimating Travel Impacts

Logit Mode Choice Model - The impact of travel time or cost strategies on travel behavior are determined in the COMMUTER model through use of an analytical technique known as a *logit mode choice model*. Models of this type are considered to be the state of the practice in transportation planning and policy studies. Most major metropolitan areas have developed these models from local data and use them routinely within their regional planning process. They are used by metropolitan planning agencies for developing regional plans, analyzing the impact of major investment alternatives, or responding to regulatory requirements (such as conformity analysis).

Logit mode choice models are particularly appropriate for examining traveler response to change in travel time or travel cost. Their structure explicitly includes the various elements of time and cost that were discussed in the previous section. The value of these elements to the traveler is reflected through *coefficients* that have been developed through a statistical estimation process applied to extensive regional travel data. The structure of the model also expressly incorporates the very practical consideration of determining the effect of having several strategies operating at the same time—possibly differently on the individual modes—and having the modes compete with each other based on their relative cost and time advantages.

A logit mode choice model relates the *utility* or "attractiveness" of a travel mode to the consumer in relation to the utility of the alternatives. The traveler selects the mode that maximizes his/her utility, i.e., which provides the greatest total value. The model does this by calculating the statistical probability that each mode will be chosen, and the individual is presumed to choose the mode with the highest probability. When this process is performed for a travel population, rather than an individual traveler, the probabilities become modal shares. For example, if the model computes probabilities of 0.758 for drive alone, 0.133 for transit, and 0.109 for carpool, the individual would be expected to drive alone, since drive alone commands the highest probability. However, if these probabilities were obtained as the result of applying the model to a population of travelers, the probabilities would signify mode shares for that group, i.e., 75.8% would drive alone, 13.3% would use transit, and 10.9% would ride in carpools.

In the logit model, the share of each available mode depends on the existence and relative attractiveness of other available travel modes. The probability structure ensures that the total of the shares of all modes will not exceed 100%.

The probability of selecting a given travel mode *m* is calculated through the following equation:

$$P(m) = \frac{e^{um}}{e^{u1} + e^{u2} + \ldots. + e^{ui}}$$

where

> *p(m)* is the share of mode m;
>
> *e* is the exponential function (*e* to the power *x*, where *e* = 2.7183);
>
> u_m is the utility equation for mode m; and
>
> $u_1...u_i$ represents the utility of other available modes 1 through i.

The utility of each alternative mode is usually a linear function that incorporates the important choice attributes of the mode, such as travel time and cost, coupled with weights, or *coefficients,* that represent the relative importance of the attributes to the traveler. Logit mode choice model coefficients are typically calculated from household travel survey data using a statistical curve-fitting technique known as maximum likelihood estimation. A typical utility function might look like the following:

$$U_{(auto)} = c + a(\text{time}) + b(\text{cost})$$

Where:

$U_{(auto)}$ is the utility of the auto mode;

time and cost represent travel time and cost for the trip using auto;

c is a constant representing the utility of the mode that is not captured by travel time or cost; and

a and *b* are coefficients applied to time and cost, respectively.

This equation produces an S-shaped curve, as shown in Figure 6-1. The graph shows the percentage use of mode *m* as a function of the *disutility* of mode *m*.[*] A distinguishing feature of this curve is that its slope is steepest in the middle, and this is where small changes in utility have the greatest effect on mode share. At the high and low end of the curve, the curve flattens out, indicating that even relatively large changes in utility have little impact on the mode's share at that point.

The Pivot-Point Approach - In the COMMUTER model, just as in the FHWA TDM Model, the logit procedure is applied in what is known as a *pivot point* approach. In a traditional application of a logit mode choice model in a regional planning study, it would

Figure 6-1

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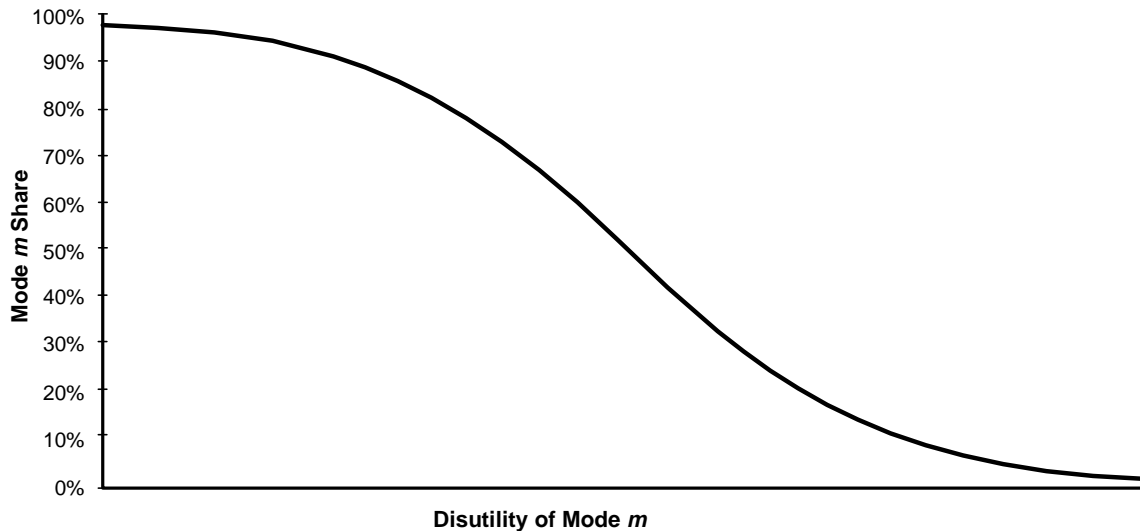
[*] While the traveler choosing among alternatives attempts to "maximize his utility" when picking his preferred alternative, in the case of travel mode choice where the key attributes are time and cost, the best alternative is the one that offers the *least* time and cost. In this situation, because higher values of time and cost are seen as *disutility*, the consumer's selection of the best alternative is instead a process of "*minimizing* his/her disutility."

be necessary to relate to the model detailed information on the time, cost and other relevant factors for each alternative, and for each traveler or origin destination pair that make up the analysis. This must be done for each alternative or policy analyzed, requiring a significant amount of time and effort.

The pivot point approach is a less data-intensive method for applying logit mode choice models. Rather than gathering information on the time and cost components for each mode for each trip, the analyst has only to describe how much travel time or cost

components will *change* as a result of the test strategies. In the pivot point approach, the logit model is not used to estimate a mode share, but to estimate the *change* in a known mode share, given a *change* in transportation system characteristics. In this case, the procedure starts with a set of mode shares and an assumed change in travel time or travel cost for each mode. The same logit coefficients described above can then be used to estimate what the new mode shares would be. The mathematical expression for this, which can be derived from the basic logit model equation, is as follows:

$$ p'(m) \quad = \quad \frac{p(m) \times e^{-\Delta U(m)}}{[(e^{-\Delta U(m)} - 1) \times p(m)] + 1} \tag{1} $$

where:

$p'(m)$ = original share of mode *m*
$p(m)$ = the new share of mode *m*
$\Delta U(m)$ = the change in disutility of mode *m* = *a* (Travel Time) + *b* (Travel Cost)

Because this equation does not contain any reference to the original (or background) values of travel time or Travel Cost, it is not necessary for the user to know those values or any other conditions about the original trip. All of that information is "contained" in the utility value for the original mode share. Thus, the user only needs to inform the model of the starting mode shares, and the procedure will "pivot" off the point described by the existing shares and adjust those shares in relation to the magnitude of time or cost changes introduced by the scenario and the mathematical relationships in the logit equation.

As indicated in the preceding section, mode shares predicted by a logit model follow an S-shaped curve relationship between disutility for a mode and the probability of its choice, or, as shown in Figure 6-2, the Modal Share.

As Figure 6-2 illustrates, a given mode *m* has a starting share of 10%. A strategy or set of strategies is applied that reduces the disutility of using mode *m* by a particular amount, and this change improves the attractiveness of mode *m* sufficient to increase its share to 30%. The reader can readily see that if the starting share for mode *m* were different from 10%, then the same change in disutility would produce a very different outcome in resulting share. If the starting share were higher, the predicted increase would be greater; if it were smaller than 10%, the predicted change in share would be less than in the example.

"Seeding" of a Zero Share Mode - One limiting characteristic of the pivot point approach occurs when one of the modes being targeted for change has an initial share of "zero." This is the case if, for example, transit or vanpool were to be introduced under a

commuter choice program, but there was no current history of use with that mode. Because the pivot point approach requires some initial share value to pivot from, any time

Figure 6-2
Modal Share

Y-axis: Mode m Share (0% to 100%)
X-axis: Disutility of Mode m
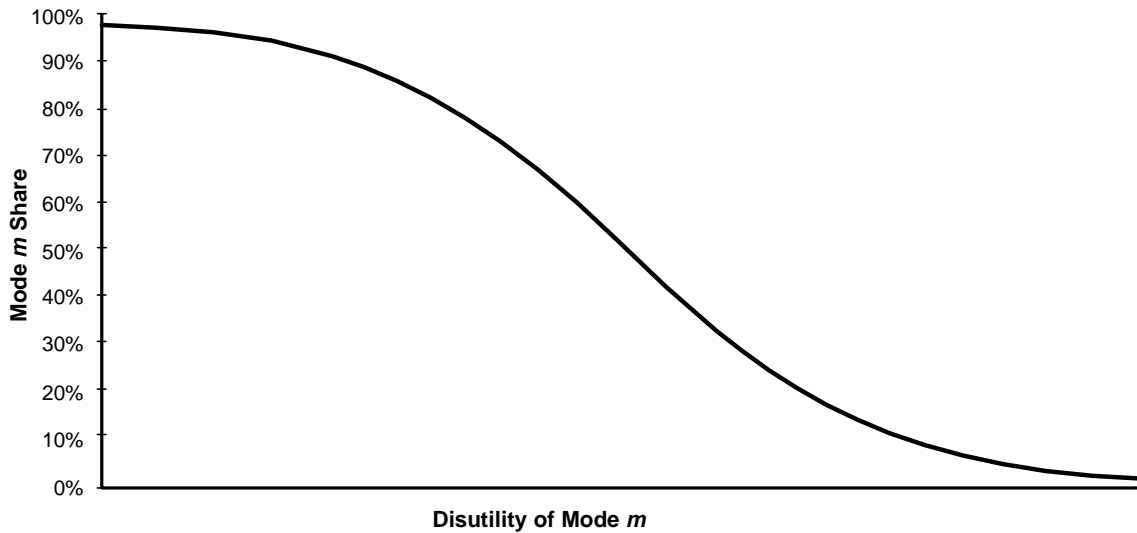
or cost changes introduced through a set of strategies would have nothing to pivot from, and the model would predict no change.

There are two basic ways of dealing with this situation:

1. A nominal starting share can be assumed, such as 0.1%. While the changes induced in this share through time or cost incentives will be small, they will at least register the mode as part of the alternative choice set.

2. The user can first employ one of the Employer Support Strategies (Chapter 4), which serves to arithmetically *add* an incremental share to what is already there. If the starting share is 0% and the user specifies a program that *increases* share by 2%, then the starting share for the zero mode becomes 2% for subsequent application of time or cost strategies when the procedure reaches the logit pivot-point procedure at the end of the computation process.

If the user does not employ option (2) above, the COMMUTER model has been set up to enter a default share of 0.1% for modes that enter the logit pivot point process with zero starting share <u>and</u> that have time or cost strategies targeted at them.

Coefficients Used in Pivot-Point Logit Model Approach

The weights used in the utility expression of the logit model are coefficients, derived from statistical analysis of relationships embedded in travel survey data. Generally, these coefficients are developed from an estimation process using local survey data. Following the 1990 Census, many (if not most) metropolitan areas conducted new urban travel surveys for the purpose of updating and upgrading models that had been developed from data last collected in the 1970s or 1960s. Some areas do not conduct travel surveys and develop new models from scratch because these are very resource intensive and mathematically challenging exercises. Rather they will "borrow" models and coefficients from other areas believed to be similar in character, and "calibrate" the models to their own situation using modest local information. Areas that have their own existing travel demand models that were developed from very dated information may opt to simply update their coefficients from modest new information and "calibrate" those coefficients to where they replicate local behavior when tested.

The logit pivot point procedure in the COMMUTER model incorporates coefficients for the following time or cost elements:

Coefficient	Strategies Applied to:
In-Vehicle Travel Time (IVTT)	Faster Transit Service
Out-of-Vehicle Time (OVTT), Walk Time	Walk Access Time for: - Auto drive alone - Carpool - Vanpool - Transit - Bicycle - Pedestrian
Out-of-Vehicle Time (OVTT), Wait Time	Transit Wait (or Transfer) Time
Auto Out-of-Pocket Cost	Parking Cost for: - Drive Alone - Carpool - Vanpool
Transit Cost	Transit Fare

COMMUTER model users are asked to indicate what coefficient values they will use in their analysis. The model provides for two alternatives:

- **Site Specific Coefficients**: All users are encouraged to obtain and use the coefficients that have been specifically developed for their respective area by the regional planning agency, or MPO. Coefficients have been compiled for a large number of U.S. metropolitan areas, and have been incorporated into the COMMUTER model. Users may search the menu for their respective areas, and if it is included in the list, simply click on the choice to load those coefficients into the model. Table 6-2 lists the sites that are included in the COMMUTER model at this time, and the respective values of their coefficients.

Table 6-2 Logit Mode-Choice Coefficients for Individual Urban Areas							
			In-Vehicle Travel Time (min)	Out-of-Vehicle Travel Time (min)		Out-of-Pocket Travel Cost (cents)	
Location	Area Size	Year	All Modes	Walk Time	Transit Wait	Auto Parking	Transit Fare
Albuquerque	Small	1992	-0.0209	-0.0219	-0.0978	-0.0031	-0.0031
Boston	Large	1991	-0.0165	-0.0330	-0.0550	-0.0173	-0.0083
Chicago	Large	1990	-0.0282	-0.0440	-0.0960	-0.0021	-0.0008
Cincinnati	Medium	1978	-0.0190	-0.0280	-0.0280	-0.0050	-0.0050
Cleveland	Large	1994	-0.0178	-0.0444	-0.0378	-0.0034	-0.0024
Dallas	Large	1984	-0.0297	-0.0552	-0.0552	-0.0116	-0.0046
Denver	Medium	1985	-0.0180	-0.0540	-0.0282	-0.0095	-0.0044
Detroit	Large	1965	-0.0457	-0.0641	-0.1165	-0.0065	-0.0065
Houston	Large	1994	-0.0220	-0.0568	-0.0568	-0.0154	-0.0061
Los Angeles	Large	1991	-0.0210	-0.0530	-0.0530	-0.0030	-0.0030
Milwaukee	Medium	1991	-0.0160	-0.0410	-0.0410	-0.0045	-0.0045
Minneapolis	Large	1970	-0.0310	-0.0440	-0.0300	-0.0140	-0.0140
New Orleans	Medium	1960	-0.0150	-0.0330	-0.0770	-0.0080	-0.0080
Philadelphia	Large	1986	-0.0420	-0.0320	-0.0510	-0.0026	-0.0012
Phoenix	Large	1997	-0.0195	-0.0257	-0.0308	-0.0111	-0.0055
Pittsburg	Large	1978	-0.0467	-0.0687	-0.0687	-0.0210	-0.0210
Portland	Medium	1985	-0.0390	-0.0650	-0.0400	-0.0135	-0.0135
Reno	Small	1991	-0.0275	-0.0550	-0.0550	-0.0167	-0.0067
Sacramento	Medium	1991	-0.0250	-0.0380	-0.0380	-0.0028	-0.0028
San Francisco	Large	1990	-0.0333	-0.0931	-0.0523	-0.0021	-0.0021
San Juan	Medium	1990	-0.0366	-0.0717	-0.0752	-0.0066	-0.0066
Santa Cruz	Small	1990	-0.0163	-0.0325	-0.0325	-0.0045	-0.0036
St Louis	Large	1965	-0.0228	-0.0570	-0.0570	-0.0117	-0.0117
Tucson	Small	1993	-0.0180	-0.0400	-0.0400	-0.0018	-0.0018
Wash DC	Large	1980	-0.0170	-0.0580	-0.0580	-0.0094	-0.0044

- **Default Coefficients:** For users who do not find their city in the menu, a set of default coefficients has been developed through a synthesis of the cities that are included. Default "area size" coefficients have been developed for the following three settings:

    - Large urban areas, with populations greater than 2 million;
    - Medium sized urban areas, with populations of 750,000 to 2 million; and
    - Small urban areas, with populations of fewer than 750,000.

  These area size default coefficients are listed in Table 6-3.

Table 6-3 **Default Coefficient Values**					
Metropolitan Area Size	In-Vehicle Travel Time (min)	Out-of-Vehicle Travel Time (min)		Out-of-Pocket Travel Cost (cents)	
	All Modes	Walk Time	Transit Wait	Auto-Parking	Transit-Fare
Large - over 2,000,000	-0.0281	-0.0521	-0.0584	-0.0094	-0.0065
Med. - 750,000-2,000,000	-0.0241	-0.0472	-0.0468	-0.0071	-0.0064
Small - below 750,000	-0.0207	-0.0373	-0.0563	-0.0065	-0.0038

Source: Cambridge Systematics, Inc., 1998.

Model users reflecting upon the values of the various coefficients will reach the following conclusion as to which strategies are likely to have the greatest impact. In general, cost strategies will have a greater impact (per percentage change in existing conditions) than travel cost. Auto parking costs are known to have major impact on travel choice, and this is reflected in the coefficient that is higher than any other in the group. Auto parking cost has almost twice the impact on mode choice as a change in transit fare. Among travel time elements, strategies that reduce the travel time that occurs "outside" the vehicle, i.e., where the user is either walking or waiting to connect with the mode, are generally valued more than changes that occur to the travel time once the user is "inside" the vehicle. This is because walking and waiting require more active effort from the traveler, whereas once

aboard and underway, the traveler is generally seated, comfortable, and able to use the time for some other purpose. These relationships can be a guide as to where attention should be placed when designing an effective commuter choice program.

Example Calculation of Change in Time or Cost through Logit Pivot-Point Model

The following is a simple example to illustrate how the logit pivot-point analysis procedure would evaluate a typical program that involves strategies that change travel time and cost. This example is built on the following assumptions:

- **Area type and size**: This example involves a "large" metropolitan area, and we are conducting a "regional level" analysis. Because this is a hypothetical area, the specific model coefficients for the area have not been included in the model's menu. As a result, we will use the default coefficients for a large metropolitan area supplied within the COMMUTER model. The values for these coefficients are as follows:

    IVTT (all modes)   =   - .0281 min
    OVTT (walk, all modes)   =   - 0.0521 min
    OVTT (wait time, transit)   =   - 0.0584 min
    Cost (auto parking)   =   - 0.0094 cents
    Cost (transit fare)   =   - 0.0065 cents

- **Current Mode Shares:** The following default modal shares are assumed:

    Drive Alone: 75.4%
    Carpool: 13.2%
    Vanpool: 0.5%
    Transit: 5.3%
    Bicycle: 0.4%
    Walk: 4.0%
    Other: 1.1%

- **Strategies:** The following time and cost related strategies will be included in the test scenario:

    Access Time Changes:
    Preferential parking: Drive alone, +2 min.; Carpool, -1 min.; Vanpool, -1 min.
    Site Access improvements: Transit: -2 min.; Bike: -2 min.: Walk: -2 min.

Transit Service Improvements:
More Frequent Service (Less Wait Time): Transit, -2.5 minutes
Faster Service (Less Travel Time): Transit, -5.0 min.

Travel Cost Changes:
Parking Charges: Drive Alone, +$1; Carpool, $0; Vanpool, -$2
Transit Subsidy: Transit, -$1 per day

The first step taken by the model will be to recompute the change in utilities for each mode [$-\Delta U(m)$], as follows:

Drive Alone:

$$-\Delta U_{DA} = -0.0521\ (\Delta OVTTWalk_{DA}) - 0.0094\ (\Delta Parking\ Cost_{DA})$$
$$= -0.0521 \times (2\ min) - 0.0094 \times (\$1) \times 100\ cents/\$ = -1.0442$$

Carpool:

$$-\Delta U_{CP} = -0.0521\ (\Delta OVTTWalk_{CP}) - 0.0094\ (\Delta Parking\ Cost_{CP})$$
$$= -0.0521 \times (-1\ min) - 0.0094 \times (\$0) \times 100\ cents/\$ = 0.0521$$

Vanpool:

$$-\Delta U_{VP} = -0.0521\ (\Delta OVTTWalk_{VP}) - 0.0094\ (\Delta Parking\ Cost_{VP})$$
$$= -0.0521 \times (-1\ min) - 0.0094 \times (\$-2) \times 100\ cents/\$ = 1.9321$$

Transit:

$$-\Delta U_{TR} = -0.0281\ (\Delta IVTT_{TR}/2) - 0.0521\ (\Delta OVTTWalk_{TR}) -$$
$$0.0584\ (\Delta OVTTWait_{TR}/2) - 0.0065\ (\Delta Fare\ Cost_{TR})$$
$$= -0.0281 \times (-5\ min/2) - 0.0521 \times (-2\ min) -$$
$$0.0584 \times (-2.5\ min/2) - 0.0065 \times (\$-1) \times 100\ cents/\$ = 0.8975$$

(Note that the changes in transit service frequency and time are divided by two to reflect two-way commute trips being applied to daily coefficients.)

Bicycle:

$$-\Delta U_{BK} = -0.0521\ (\Delta OVTTWalk_{BK})$$
$$= -0.0521 \times (-2\ min) = 0.1042$$

Walk:

$$-\Delta U_{WK} = -0.0521\ (\Delta OVTTWalk_{WK})$$

$$= -0.0521 \times (-2 \text{ min}) = 0.1042$$

Next, revised mode shares are computed using equation (1):

$$
\begin{aligned}
\text{P'}_{DA} &= [\text{P}_{DA} \times exp \,(-\Delta\text{U}_{DA})] \;/\; \{[(exp \,(-\Delta\text{U}_{DA}) - 1) \times \text{P}_{DA}] + 1\} \\
&= [0.754 \times e^{\,-1.0442}] \;/\; \{[(e^{\,-1.0442} - 1) \times 0.754] + 1\} \\
&= 0.2655 \,/\, 0.4460 \;=\; 0.5953 \;=\; 59.53\%
\end{aligned}
$$

$$
\begin{aligned}
\text{P'}_{CP} &= [\text{P}_{CP} \times exp \,(-\Delta\text{U}_{CP})] \;/\; \{[(exp \,(-\Delta\text{U}_{CP}) - 1) \times \text{P}_{CP}] + 1\} \\
&= [0.132 \times e^{\,+0.0521}] \;/\; \{[(e^{\,+0.0521} - 1) \times 0.132] + 1\} \\
&= 0.1393 \,/\, 0.8862 \;=\; 0.1572 \;=\; 15.72\%
\end{aligned}
$$

$$
\begin{aligned}
\text{P'}_{VP} &= [\text{P}_{VP} \times exp \,(-\Delta\text{U}_{VP})] \;/\; \{[(exp \,(-\Delta\text{U}_{VP}) - 1) \times \text{P}_{VP}] + 1\} \\
&= [0.005 \times e^{\,+1.9321}] \;/\; \{[(e^{\,+1.9321} - 1) \times 0.005] + 1\} \\
&= 0.0345 \,/\, 0.9952 \;=\; 0.0347 \;=\; 3.47\%
\end{aligned}
$$

$$
\begin{aligned}
\text{P'}_{TR} &= [\text{P}_{TR} \times exp \,(-\Delta\text{U}_{TR})] \;/\; \{[(exp \,(-\Delta\text{U}_{TR}) - 1) \times \text{P}_{TR}] + 1\} \\
&= [0.053 \times e^{\,+0.8975}] \;/\; \{[(e^{\,+0.8975} - 1) \times 0.053] + 1\} \\
&= 0.1308 \,/\, 0.9537 \;=\; 0.1371 \;=\; 13.71\%
\end{aligned}
$$

$$
\begin{aligned}
\text{P'}_{BK} &= [\text{P}_{BK} \times exp \,(-\Delta\text{U}_{BK})] \;/\; \{[(exp \,(-\Delta\text{U}_{BK}) - 1) \times \text{P}_{BK}] + 1\} \\
&= [0.004 \times e^{\,+0.1042}] \;/\; \{[(e^{\,+0.1042} - 1) \times 0.004] + 1\} \\
&= 0.0044 \,/\, 0.9960 \;=\; 0.0045 \;=\; 0.45\%
\end{aligned}
$$

$$
\begin{aligned}
\text{P'}_{WK} &= [\text{P}_{WK} \times exp \,(-\Delta\text{U}_{WK})] \;/\; \{[(exp \,(-\Delta\text{U}_{WK}) - 1) \times \text{P}_{WK}] + 1\} \\
&= [0.040 \times e^{\,+0.1042}] \;/\; \{[(e^{\,+0.1042} - 1) \times 0.040] + 1\} \\
&= 0.0446 \,/\, 0.9616 \;=\; 0.0464 \;=\; 4.64\%
\end{aligned}
$$

(Note that the revised share for the other (e.g., telecommute) mode is still 1.1% since it is unaffected by these specific strategies.)

Final mode shares are then determined by normalizing the revised shares (to total 100%):

| Mode	Revised	Normalization		Final
Drive Alone	59.67%	0.5953 ÷ 0.9861	=	60.4%
Carpool	15.72%	0.1572 ÷ 0.9861	=	15.9%
Vanpool	3.47%	0.0347 ÷ 0.9861	=	3.5%
Transit	13.71%	0.1371 ÷ 0.9861	=	13.9%
Bicycle	0.45%	0.0045 ÷ 0.9861	=	0.5%
Walk	4.64%	0.0464 ÷ 0.9861	=	4.7%
Other	1.10%	0.0110 ÷ 0.9861	=	1.1%
Total	98.61%			100.0%

###

7. Converting Travel Impacts to Emissions Reductions

Overview of Procedure

Once the basic travel impacts for a given set of strategies have been calculated as described in Chapters 4, 5, and 6, the COMMUTER model then proceeds to estimate the corresponding change in emissions. This procedure is illustrated in Figure 7-1.

Figure 7-1
Translation of Travel Demand Changes into
Emissions Reductions
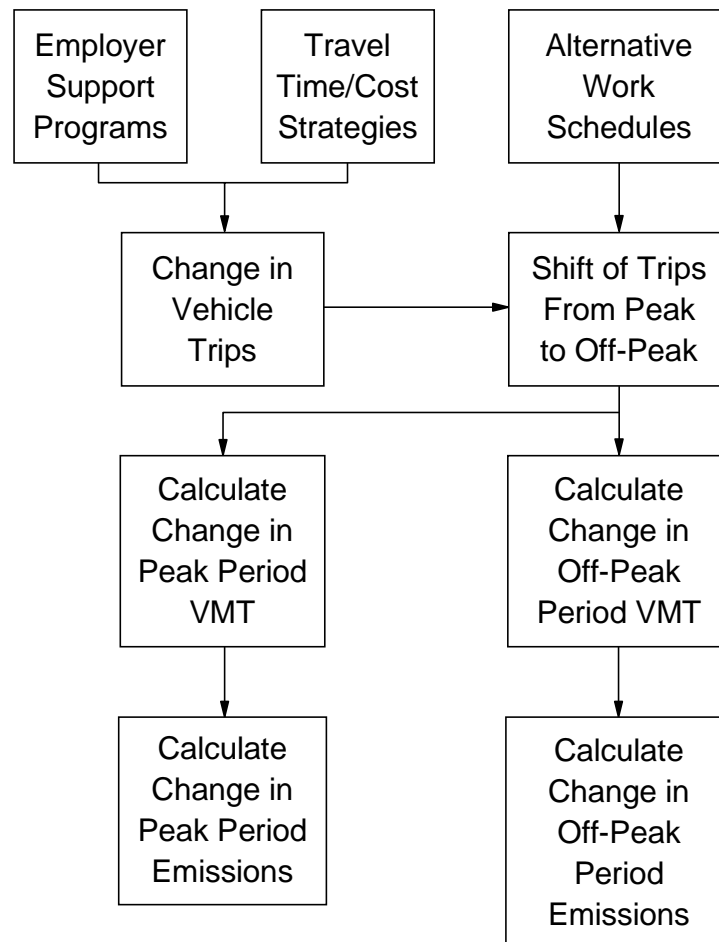
The changes in travel result from application of Employer Support Programs, Travel Time or Cost Strategies, and Alternative Work Schedules. As pictured in Figure 7-1, the first of these two strategy groups produces changes in overall trip making (i.e., number of vehicle trips), while the Alternative Work Schedules strategies produce changes in the time that the trips occur, namely in the Peak or Off-Peak.

The change in modal split induced by the Employer Support Programs and the Time/Cost Strategies is mated with information about average modal trip lengths, and used to calculate the change in vehicle miles of travel (VMT). In combination with the information on the proportion of trips shifted from peak to off-peak, the COMMUTER model then calculates the change in VMT in both peak and off-peak periods.

Using the change in VMT for the two time periods, the COMMUTER model then applies per-mile vehicle emissions rates (or factors) to these VMT estimates to produce an estimate of the change in emissions due to the particular analysis scenario. Emissions changes are calculated for hydrocarbons (HC), oxides of nitrogen (NOx), and carbon monoxide (CO).

The procedures and assumptions associated with each of these steps are presented in the sections below.

Changes in Total Trips

Once final mode shares have been calculated based on application of the lookup table or logit pivot-point model techniques, these mode shares are used to estimate changes in vehicle-trips and VMT. The model calculates the percentage of *persons* who will travel by each mode. For example, assume that the affected travel population consists of 5,000 employees, and the starting mode shares are as follows:

Drive Alone:	75.4%
Carpool:	13.2%
Vanpool:	0.5%
Transit:	5.3%
Bicycle:	0.4%
Walk:	4.0%
Other:	1.1%
	100%

Then 5,000 x 0.754 = 3,770 people would drive alone, 660 would travel by carpool, 25 would travel by vanpool, etc. To determine the number of vehicle trips represented by this population's modal distribution, it is necessary to divide each vehicular mode by its passenger occupancy. Only the drive alone, carpool, and vanpool modes are assumed to generate vehicle trips in this computation; transit, bicycle, walking and other are not

associated with making of a private motor vehicle trip. Passenger occupancy for drive alone is, of course, 1.0. Default values of 2.2 persons are assumed for carpools, and 6.0 persons for vanpools. The user has the option of changing these assumptions if better information is available locally.

The vehicle trips generated by the example population in relation to the starting mode shares would be as follows:

Drive Alone: $3,770 \div 1.0$ persons $=$ 3,770 vehicle trips
Carpool: $660 \div 2.2$ persons $=$ 300 vehicle trips
Vanpool: $25 \div 6.0$ persons $=$ 4.2 vehicle trips

for a total of 4,074 vehicle trips being generated by this population of 5,000 employees.

Whether these are regarded as only one-way trips or daily round trips depends on how the analyst has defined them in the database. In the COMMUTER model these would be daily round trips, meaning that it would be necessary to multiply 4,074 vehicle round trips by 2, to yield 8,148 <u>daily</u> vehicle trips.

The same process is then applied to the new mode shares to arrive at the *change* in vehicle trips produced by the test scenario. To illustrate, assume that the test scenario brought about the following new pattern of mode shares:

Drive Alone: 72%
Carpool: 15%
Vanpool   2%
Transit: 6%
Bicycle: 1.5%
Walk: 7%
Other: <u>0.5%</u>
                100%

The new vehicle trip total generated by this population would be calculated as follows:

5,000 persons $[(0.72)/(1.0)_{DA} + (0.15)/(2.2)_{CP} + (0.02)/(6.0)_{VP}] \times 2$

or 7,916 vehicle daily trips

So the tested scenario in this case would reduce vehicle trips by $8,148 - 7,916 = 232$ trips.

Changes in Total VMT

To convert changes in trips to changes in VMT, the COMMUTER model applies information on average trip length for each of the modes to the modal split for both existing and new conditions. An average trip length is specified in the model for each mode. While the user is invited to supply local values where they are available, the following defaults have been coded into the model:

Drive Alone:	11.85 miles
Carpool:	12.21 miles
Vanpool:	17.70 miles
Transit:	11.42 miles
Bicycle:	1.80 miles
Walk:	1.00 miles
Other:	11.42 miles
Average	11.42 miles

The COMMUTER model would calculate <u>baseline</u> VMT for the 5,000 employee example used above as follows:

> Total VMT = [(3,770 DA trips) x (11.85 miles) + (300 CP trips) x (12.21 miles)
> + (4.2 VP trips) x (17.70 miles)] x 2 trips per day
>   = 96,824 daily VMT

When a test scenario has been applied that changes mode split, a slightly different procedure is used to calculate the new VMT. The reason for this is the assumption that, when travelers are taken from the drive alone mode and shifted to a new mode, they also assume the trip length of that new mode. Hence the trips diverted from drive alone are assumed to reduce the cumulative VMT for drive alone by the amount of the new mode's trip length. Assume, for example, that an auto driver shifted to vanpool. The average trip length for a vanpool trip is 17.7 miles, compared to 11.85 for the drive alone. So the shifted trip in this case would deduct 11.85 daily drive alone VMT, and add 17.7 miles *divided by* 6.0 occupants, or 2.95 miles after switching to vanpool, for a net change of –8.9 miles.

To effect this debit and credit accounting for VMT based on which modes are exchanging riders, the following rules guide the analysis:

1. The overall average person-trip length for all individuals making a work-trip remains the same (i.e., no one changes the location of their workplace or residence as a result of the implemented programs).

2. Average person trip-lengths for *all modes except drive-alone* remain _fixed_ before and after the program. This means, for example, that those who shift from driving alone to bicycling have shorter-than-average trip lengths, while those who shift from driving alone to vanpooling have longer-than-average trip lengths.

3. Trips eliminated due to telecommuting or compressed work weeks are assumed to be the same length as the overall average person-trip, so that elimination of these trips does not change the average person or motor-vehicle trip length. (This conservative approach assumes that the average trip lengths will remain the same, even with a reduction in the number of automobiles using the transportation system as a result of increased telecommuting or compressed work weeks.)

4. The average person-trip length for drive-alone commuters is then re-computed so that the overall average person-trip length is the same as it was before implementation of the programs.

An illustration of how this calculation would be performed is shown in the following table using the previous 5,000 employee example.

Mode	Starting Share	Average Trip Length	Daily VMT	New Mode Share	New Avg. Trip Length	New Daily VMT
D. Alone	75.4%	11.85	89,349	72%	**11.66**	83,952
Carpool	13.2%	12.21	7,326	15%	unchanged	8,325
Vanpool	0.5%	17.70	149	2%	unchanged	590
Transit	5.3%	11.42	0	6%	unchanged	0
Bike	0.4%	1.80	0	1.5%	unchanged	0
Walk	4.0%	1.00	0	7%	unchanged	0
Other	1.1%	11.42	0	0.5%	unchanged	0
Total	**100%**	**11.42**	**96,824**	**100%**	unchanged	**92,867**

The baseline mode shares combined with the baseline average trip lengths produce 96,824 total daily VMT. Under the test scenario, the mode shares are changed as shown in column 5. To calculate the associated new VMT, a new average trip length must be calculated for drive alone. It is assumed that all other modes retain their original average trip length and that overall average trip length remains at 11.42 miles, so that any changes in individual trip length are assumed to occur in the drive alone mode. To calculate the

adjusted drive alone trip length, the new shares in column 5 are used to weight the original trip lengths (for all modes except drive alone), and then the new drive alone trip length that preserves the original 11.42 mile overall trip length is calculated by solving the following equation for ATL_{DA}:

$$(0.72 \times ATL_{DA}) + (0.15 \times 12.21) + (0.02 \times 17.7) + (0.06 \times 11.42) + (0.015 \times 1.8) + (0.07 \times 1.0) + (0.005 \times 11.42) = 11.42$$

Solving for ATL_{DA} yields 11.66 miles for the revised drive alone trip length. Using these new shares and average trip lengths, the daily VMT resulting from the new scenario is calculated as 92,867.

As an additional input to the emission calculations, average motor-vehicle trip lengths (existing and new) must be also be computed. The average motor-vehicle trip length ($ATL_{Motor\ Vehicle}$) is simply the average of trip lengths for the drive-alone, carpool, and vanpool modes, weighted by the mode shares for each mode. For the example above, these values would be calculated as follows:

$$\text{Baseline } ATL_{Motor\ Vehicle} = (75.4\% \times 11.85) + (13.2\% \times 12.21) + (0.5\% \times 17.70)$$

$$= 10.64 \text{ miles}$$

$$\text{Post-Scenario } ATL_{Motor\ Vehicle} = (72\% \times 11.66) + (15\% \times 12.21) + (2.0\% \times 17.70)$$

$$= 10.58 \text{ miles}$$

Allocation Between Peak Period and Off-Peak

Once the changes in vehicle trips and VMT due to the tested scenario have been computed, the next step before calculating the emissions impacts is to reallocate the trips and VMT between the peak and off-peak periods. This adjustment would be necessary only if the scenario had also included Alternative Work Schedule strategies that affected the timing of trips. Specifically, this would be the result of applying Flexible Work Hours or Staggered Work Hours strategies.

The COMMUTER model begins with an initial allocation of trips between the peak and off-peak periods. This is done by first computing the number of vehicle trips and VMT for the "affected employment" using the methods above, and then using information provided by the user on the percentage of daily commute trips that occur in the peak period. This factor, appearing on the Local Data screen of the model as Percent of Work

Trips in Peak Period, is supplied with a default computed from national data of 61.7%.[*] The user is encouraged to supply local information for this value if available.

When Flexible Work Hours or Staggered Work Hours strategies are applied in a program scenario, the COMMUTER model estimates the percentage of trips that would shift the time of travel from the peak to the off-peak periods (process discussed in detail in Chapter 5). As part of this calculation, the COMMUTER model also takes into account the length of the peak period. For areas where the peak period lasts the "standard" three hours, the model predicts that 13.9% of the eligible employee trips will actually be shifted "outside" the three-hour peak period. If the peak period is shorter, say two hours, a higher percentage (28.7%) of trips will be shifted, whereas if the peak is unusually long, say four hours, then only 8.5% will be shifted. The user is asked to supply the model with the length of the local peak period, if it is different from the 3.0 hour default that is provided in the model. The information in Table 5-1 is repeated below in Table 7-1 to illustrate the relationship between length of peak period and percent of trips shifted that is used in the model.

Table 7-1	
Percent of Trips Shifted by Length of Peak Period	
Length of Peak Period (hrs)	Percent of Trips Shifted
2.0	28.7
2.5	19.2
3.0	13.9
3.5	10.6
4.0	8.5
4.5	7.1
5.0	6.0

Source: *Estimating the Effect of Alternative Work Schedules on Travel Activity and Emissions, FHWA TDM Evaluation Model*, 1993

The sample illustration is used below to provide an example of how the COMMUTER model would perform an allocation of trips between peak and off-peak based on Alternative Work Schedule programs and local information about the duration of the peak period and the current share of commute trips occurring in the peak. The calculation process is described below.

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[*] 1995 Nationwide Personal Transportation Survey, Federal Highway Administration.

The model first determines the distribution of baseline trips that occur in the peak and off-peak periods. The user has selected the default of 61.7% to represent the percentage of these trips that are occurring in the peak and off-peak periods:

Peak-Period Trips = 5,000 person trips x 0.617 = 3,085
Off-Peak Trips = 5,000 person trips x 0.383 = 1,915

(Note that these are daily round trips; if the individual home-to-work and return work trips are to be separated, the basis would increase to 10,000 one-way trips. Care should be taken when calculating VMT that the basis is consistent with whether the user is assuming daily or one-way VMT and emissions.)

Assuming the same baseline mode shares as previously, this would produce the following peak and off-peak vehicle trip and VMT allocation:

Mode	Starting Share	Daily Vehicle Trips	Daily VMT	Daily Peak Vehicle Trips	Daily Peak VMT	Daily Off-Peak Vehicle Trips	Daily Off-Peak VMT
D. Alone	75.4%	7,540	89,349	4,652	55,128	2,888	34,220
Carpool	13.2%	600	7,326	370	4,520	230	2,805
Vanpool	0.5%	8.4	149	5.2	92	3.2	57
Transit	5.3%	0	0	0	0	0	0
Bike	0.4%	0	0	0	0	0	0
Walk	4.0%	0	0	0	0	0	0
Other	1.1%	0	0	0	0	0	0
Total	**100%**	**8,148**	**96,824**	**5,027**	**59,740**	**3,121**	**37,083**

When the hypothetical scenario is then applied that changes the mode shares, the table above changes to the following:

Mode	Revised Mode Shares	Daily Vehicle Trips	Daily VMT	Daily Peak Vehicle Trips	Daily Peak VMT	Daily Off-Peak Vehicle Trips	Daily Off-Peak VMT
D. Alone	72%	7,200	83,952	4,442	55,128	2,758	34,220
Carpool	15%	681	8,325	420	4,520	261	2,805

Vanpool	2%	16.7	590	10.3	92	6.4	57
Transit	6%	0	0	0	0	0	0
Bike	1.5%	0	0	0	0	0	0
Walk	7%	0	0	0	0	0	0
Other	0.5%	0	0	0	0	0	0
Total	**100%**	**7,898**	**92,867**	**4,872**	**57,299**	**3,026**	**35,568**

Now if the test scenario applies a Flexible Work Hours program strategy that assumes that 30% of all employees will be eligible for the program, the following impacts would be calculated (and assuming zero existing eligibility):

First, the model calculates the number of employees who would be affected as:

5,000 employees x 61.7% in peak x 80% office x 30% eligible

= 740 employee trips eligible for shifting

Next, the model determines how many trips may be shifted outside the peak period based on the length of the peak period. In this example, it is assumed that the peak period has a 3.0 hour duration. Hence the model would assume that 13.9% of the eligible trips would actually shift to the off-peak. Coupled with the default participation rate of 22%, the example yields:

740 person trips x 13.9% x 22% = 23 person trips shifted from peak to off-peak

(23 x 2 = 46 per day)

Those person trips would be presumed to shift from peak to off-peak in the same proportion as the modal shares for all affected employees as engineered by the test scenario. In other words, the person trips shifted would be at the rate of 72% drive alone, 15% carpool, 2% vanpool, 6% transit, 1.5% bicycle, 7% walk, and 0.5% other. Thus, for each person trip shifted, the model in this case would shift:

7,898/10,000 = 0.7898 vehicle trips

and

92,867/10,000 = 9.29 VMT

So if the Flexible Work Hours strategy tested would shift 23 daily person trips, the model would remove 23 x (2 directions) x 0.7898 = 36 vehicle trips from the peak period(s) and move them to the off-peak, and similarly shift 23 x 2 x 9.29 = 427 daily VMT from the peak to the off peak.

	Pre-Scenario	Change	Post Scenario
Daily Vehicle Trips, Peak	4,872	- 36	4,836
Daily VMT, Peak	57,299	- 427	56,872
Daily Vehicle Trips, Off-Peak	3,026	+36	3,062
Daily VMT, Off-Peak	35,568	+427	35,995

This would be the new distribution of vehicle trips and VMT by time of day that would be taken forward into the emissions analysis.

Emission Impacts Methodology

The COMMUTER model uses the estimates of travel changes described above as the means for computing corresponding emission reductions.

In a full analysis of travel and emissions impacts such as would occur in the regional planning process when demonstrating SIP conformity, the detailed computation of travel changes and their effect on overall regional trips, VMT, and travel speeds would be processed through the accepted emissions model. In most areas, the MOBILE5b emissions model would be used; in California, the EMFAC equivalent model would be used.

As with the traditional transportation analysis procedure that the COMMUTER model simplifies and replaces for this purpose, so too is the MOBILE emissions model a fairly time and data intensive analysis process. As a result, a simplified process has also been developed and incorporated within the COMMUTER model to be consistent in detail and accuracy with the transportation methods being employed, and maintaining the desired application ease for the user.

The computed changes in travel activity from baseline levels are coupled with MOBILE5b-based emission factors to generate daily emission reduction estimates for hydrocarbons (HC or VOCs), NOx, and CO. These reductions are computed as tons per day changes in each respective pollutant, and are computed and reported separately for peak and off-peak travel situations. This section explains the basic emissions modeling methodology that is used in the COMMUTER model. However, the complexity of the calculations in this process makes it impractical to provide easy-to-use, manual procedures for generating emission reduction estimates. Beyond this summary, the user is referred to the COMMUTER model itself to generate these estimates.

MOBILE5b Emission Factors - To eliminate the need for the user to supply emission factors representing local fleet conditions in the analysis area of interest, an extensive

series of MOBILE5b emission factors were generated to represent a variety of local conditions and loaded into the COMMUTER model. A total of 144 separate sets of emission factors were generated representing combinations of the following fleet parameters:

- Calendar year (6) - 1998, 2000, 2002, 2005, 2010, and 2020;

- Season (2) - summer and winter;

- I/M program type (3) - no I/M, basic I/M, and enhanced I/M;

- Fuel volatility class (2) - Classes B and C (corresponding to VOC Control Regions 1 and 2, respectively); and

- Fuel control program (3) - conventional gasoline, reformulated gasoline, or wintertime oxygenated gasoline.

The ambient temperature profiles used in these MOBILE5b runs were established as a function of season and fuel volatility class and were consistent with the profiles used by EPA in its reformulated fuel rulemaking analysis using the Complex Model as follows:

- Summer, Class B - 69°F to 94°F;

- Summer, Class C - 72°F to 92°F; and

- Winter, either class - 39°F to 57°F.

Fuel volatility (i.e., RVP) inputs in these MOBILE5b runs were also established in a manner consistent with EPA's assumptions by season and VOC Control Region. For the reformulated gasoline (RFG) runs, Phase I RFG was modeled in calendar year 1998, Phase II was applied in 2000 and later calendar years.

Emission factors within each set were generated for 13 speeds from 5 to 65 mph at 5 mph increments. (As explained later, they were used to model the speed impacts of TCMs on emissions.)

Separate operating mode fractions were also specified for each set of emission factors in a manner in which stabilized and starting modes could be treated separately and combined with user inputs of cold start percentages and trip length (trip length is calculated internally within the COMMUTER model). Stabilized emission factors representing the operating mode when a vehicle's engine and catalyst are fully warmed up are represented

by the combination of Bags 2 and 3 of the Federal Test Procedure (FTP).[*] In MOBILE5b parlance, operating mode fractions representing true stabilized emission factors were set to 0% cold start, 47.9% hot start, and 52.1% "stabilized." Cold start "offset" emission factors are represented by Bag 1 minus Bag 3 of the FTP and were used to model a trip-based emissions increment that occurs when the vehicle starts cold.

Evaporative running loss, hot soak, and crankcase emission factors generated by MOBILE5b for VOC were also loaded into the program. Although MOBILE5b also produces diurnal and resting loss evaporative emission factors, they were not used in the COMMUTER model calculations. These types of emission occur when the vehicle is at rest. Since it is difficult to accurately estimate changes in vehicle "parked" conditions as a result of TCMs and since these emission impacts are secondary-level effects, they were not modeled in the COMMUTER model.

Emission Reduction Calculation - Separate calculations were performed for each of the two activity parameters modeled: VMT and trips. Emission reductions from each of these travel impacts were then added together to produce combined emission reduction impacts from changes in travel due to the TCMs evaluated. Each of these calculations, described below, was performed for both the peak and off-peak periods.

First, reductions in VMT and vehicle trips due to the TCM strategies are computed by subtracting existing activity levels from the "final" (after-TCM) activity levels. Note that under a regional analysis, the existing activity levels used in the COMMUTER model are not the same as the baseline activity for the entire region. The existing activity in the model is based on affected employment, not total population.

Second, the regional speed inputs were used to linearly interpolate the stabilized emission factors by speed increment to represent these specific speeds. VMT reductions were then applied to the stabilized emission factors at the appropriate speed to compute VOC, CO, and NOx emission reductions due to changes in VMT.

Third, the number of existing and final vehicle trips were multiplied by the cold start percentages under existing and final conditions to estimate the number of cold trips for which to apply the cold start offset. The cold start offset factors were then multiplied by the number of baseline and after-TCM cold trips to produce baseline and after-TCM starting exhaust emissions of VOC, CO, and NOx. The number of total existing and final trips (whether they started cold) were multiplied by the evaporative (VOC) hot soak and crankcase emission factors to generate baseline and after-TCM emissions from these evaporative modes. Emission reductions from trip changes were then determined by subtracting these baseline emissions from the after-TCM emissions.

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[*] In earlier versions of the MOBILE and EMFAC emission factors models, Bag 2 is often referred to as that which represents stabilized emissions; however, this is not correct. Although Bag 2 is referred to as the "stabilized" bag, the stabilized portion of the FTP is actually represented by the combination of bags 2 and 3. This has been corrected in the California Air Resources Board's latest emission factor model, MVEI7G, and a similar correction will be implemented in EPA's upcoming MOBILE6 model.

Finally, the VMT- and trip-based emission reductions were summed together. Daily reductions were also summed from peak and off-peak reductions.

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Appendix A

Definition of Modeling Terms

Definition of Terms

<u>Sources for Definition of Terms</u>:

1. Manual of Regional Transportation Modeling Practice, 1993.
2. TDM Evaluation Model Documentation, 1993.

Affected Employment – Affected employment considers the amount of employees that will be impacted by a particular commuter choice support program in a given analysis area for both office and non-office categories. In the analysis presented in this Manual, the effectiveness of some programs is assumed to differ for these two employment categories. Total employment affected is also needed to calculate changes in total trips and vehicle-miles of travel (VMT).

Destination – The geographic area in which any trip terminates.

Elasticity – In a causal relationship, the elasticity of i with respect to j is the percent change in variable i with respect to the percent change in variable j.

Functional Classification – The classification of urban and rural roadways by function. Roadways at the top of the hierarchy (freeways) serve intercity and other long distance traffic movements, roadways at the bottom (local roads) provide access to land.

Home to Work Trip – A person or vehicle trip that begins either at home or work (including one trip end at work and the other at home).

HPMS – Highway Performance Monitoring System, a federally-mandated database consisting of a representative sample of highway roadways by functional classification.

Level of Program Effort - Research has shown that the impact of employer support and incentive programs and strategies vary according to the level of effort expended on the program. The level of program effort is a particularly important dimension as it defines what is actually meant by, for example, a carpool support program. This is an important distinction in the analysis presented in this Manual. The program level will vary from 0 to 4, 0 representing no program and 4 representing a program of maximum effort. These program levels are defined separately for carpooling, vanpooling, transit, and bicycle commuting. Shown below is an example of the program level definitions for a carpool support program. (Also, see the VMEPTool User Manual for program level examples for vanpool, transit, and bicycle support programs).

- Level 0 – no program.
- Level 1 – includes carpool information activities (tied in with area-wide matching) and a quarter time transportation coordinator.

- Level 2 – includes an in-house carpool matching service and/or personalized carpool candidate get-togethers (including information activities) and a quarter time transportation coordinator.
- Level 3 - includes in-house carpool matching and information services plus preferential (reserved, inside, and/or especially convenient) parking for carpools, a policy of flexible work schedules to accommodate carpools, and a half time transportation coordinator.
- Level 4 - includes in-house carpool matching and information services plus preferential parking for carpools, flexible work schedules, and a full time transportation coordinator.

Logit – A choice model formulation based on the principle that individuals maximize utility in choosing among available alternatives. The logit formulation involves specifying a utility function for each individual, with a deterministic component (that is, one which depends on characteristics of the individual and of the alternatives) and a stochastic disturbance (or error term). The logit model, follows the assumption that the error terms are independent and share the same probability distribution. Most transportation demand model systems use a logit formulation for mode choice.

Mode Share – Mode shares represent the percentage of person and vehicle travel by type of transport. Typically, mode shares are measured by drive alone (single occupant vehicles), high occupancy vehicles (carpooling, vanpooling, and other ridesharing activity), transit (bus, rail), walking, and bicycling modes of transport.

Off-Peak Period – Occurring during periods of relatively low traffic, not during a peak period. Trip making in this period typically represents mid-day, non-commute conditions occurring between 9 a.m. and 3 p.m.

Origin – The geographic location at which a person or vehicle trip begins.

Peak Hour – The hour during which the maximum traffic occurs within the defined peak period(s). The peak hour during which traffic is highest varies by roadway functional classification and place to place (i.e., origin-to-destination).

Peak Period – Whether categorized by purpose or by geographic area, person or vehicle trips occur at different rates at different times of the day. A graph of trips by time of day typically reveals one or more peaks. These peaks play a key role in conventional travel demand analysis, which focuses on maximum infrastructure need 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 home to work (commute) trips. A peak can be characterized by its maximum trip rate (in trips per unit of time) or by duration over which some threshold trip rate is maintained. The portions of the peak before and after the peak hour are called shoulders of the peak.

Peak Spreading – Lengthening of the peak period, usually accompanied by a flattening of the peak period(s).

Person Trip – The movement of a person from an origin to a destination, as opposed to the <u>vehicle trip</u> associated with the same origin-to-destination movement. A carpool carrying three people from origin-to-destination has made one vehicle trip, its occupants together have made three person trips.

Soft Programs – "Soft Programs" represent employer support and incentive programs such as site-specific employer programs. These strategies include on-site transit pass sales, rideshare matching, and guaranteed ride home programs.

Trip End – The number of vehicle or person trips ending at a given origin or destination location.

Trip Frequency – The number of trips per unit of time.

Utility – In transportation modeling, the value (positive or negative) of a particular option, usually estimated as a function of the travel option's characteristics as well as traveler or population characteristics.

Vehicle Miles of Travel (VMT) – The total usage of vehicles in miles traveling on the transportation system for a given condition – metropolitan area, corridor, facility types (freeways, arterials), or modes of transportation.

Vehicle Occupancy – For a specific group of travelers, e.g., morning peak workers, this represents the ratio of person trips to vehicle trips. It is often used as a criterion in judging the success of trip reduction programs.

Vehicle Trip – An origin-to-destination journey by a single vehicle, as opposed to a <u>person trip</u>, the origin-to-destination journey of an occupant of the vehicle. A bus carrying 40 people from an origin to a destination makes one vehicle trip, while its occupants make a total of 40 person trips.