WORKSHOP ON TRANSPORTATION AIR QUALITY ANALYSIS

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FEDERAL HIGHWAY ADMINISTRATION
NHI COURSE NO. 15265

WORKSHOP ON TRANSPORTATION AIR QUALITY ANALYSIS
PARTICIPANT'S NOTEBOOK
NHI NATIONAL HIGHWAY INSTITUTE

Contributors and Acknowledgments

This report is a result of the coordinated efforts of many individuals. Its preparation was accomplished by a team composed of the following personnel from FHWA's Planning Support Branch: Patrick DeCorla-Souza, Jerry Everett, and Victoria Bernreuter. Chris Fleet, Chief of the Planning Support Branch, provided valuable review comments. Additionally, we would like to acknowledge the contributions of the following individuals from U.S. EPA: Jon Lessler, Natalie Dobie, Kathryn Sargent.

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ABSTRACT/COURSE OUTLINE

INTRODUCTION

- Overview of analytical issues
- Purpose and structure of the course
- Interactive discussion of transportation - air quality analysis issues

MODULE I Travel Demand Forecasting Models & Land Use/Accessibility

Emphasis will be placed on the capabilities and limitations of the traditional 4-step modeling process and currently available techniques for linking accessibility changes to land use data, including:

- Current Practice
- Implications for air quality analysis
- Now requirements from EPA guidelines
- Using the 4-step process to evaluate accessibility changes

MODULE II Emission Factor Models and Travel Related Data Requirements

Emphasis will be placed on the structure, capabilities, limitations, and travel related data requirements of emission factor models, including:

- The basic structure of U.S. EPA's MOBILE models
- Base emission rates and correction factors
- Effects of the underlying assumptions of the model on data requirements
- MOBILE's use of travel related data

MODULE III Travel Model & Emission Factor Model Interactions

Emphasis will be placed on using TDF models to develop the data required as input to emission factor models, including:

- Travel activity data, including "local" VMT
- Trip length distribution
- Operating mode mixes
- Speed estimation
- Temporal and spatial distribution of travel and variation in speeds

MODULE IV VMT Estimation

Emphasis will be placed on the currently available techniques for developing reliable, credible travel estimates and forecasts. Issues to be addressed including the following:

- Developing VMT estimates for emissions inventories and conformity analyses
- Generating "off-model" VMT
- Maintaining consistency between HPMS & travel model estimates/forecasts
- VMT estimation in the "donut" areas
- Forecasting VMT growth

MODULE V Assessing TCM Effectiveness and Impacts on Emissions

Emphasis will be placed on currently available techniques for quantifying travel and emissions impacts and analyzing the cost effectiveness of different TCM strategies, including:

- Travel demand forecasting models
- Hybrid computer software
- Non-computerized sketch planning techniques

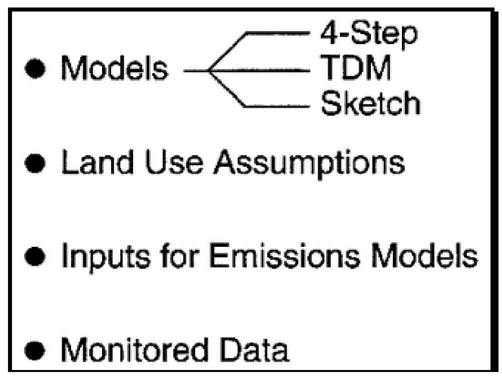
INTRODUCTION

Purpose of this Course

The purpose of this course is to provide appropriate procedures for developing various types of transportation data needed for emissions estimation.

The course will focus on:
1. technical analysis methods
2. transportation data

A separate, more comprehensive companion course "Fundamentals of Air Quality for Transportation Planning and Project Development" will be offered by FHWA beginning late summer 1994. The course will be 4 1/2 days long, and will emphasize):



1. Requirements of the Clean Air Act Amendments
2. Guidance to comply with Federal air quality requirements

Analytical Issues

Analytical issues relating to transportation "activity" estimation include the following:

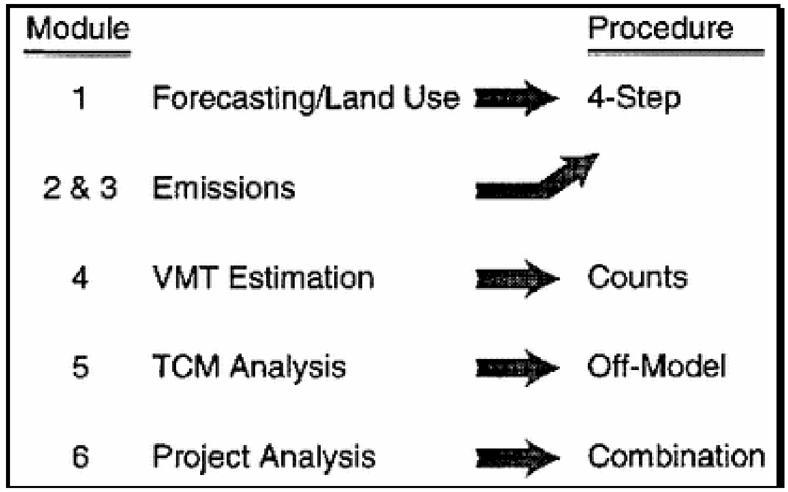
1. Travel demand four-step) models: What improvements are needed to assure travel activity estimates are suitable for air quality analysis?
2. Travel demand management (TDM) models: Which software, and which manual techniques, are suitable for estimating travel and emissions impacts of TDM/TCM actions?
3. Monitored data: What is the appropriate methodology for using monitored data (i.e. traffic counts) to forecast and track travel activity?
4. Land use inputs: How can it be assured that land use assumptions input into travel forecasting models are reasonable given transportation system changes in future?
5. Travel characteristics: How can travel characteristics other than vehicle miles of travel (VMT) needed for input to emissions models be estimated?

The above major issues (and more) are addressed in this course. Modules in which the issues are addressed are identified on the facing page.

Course Structure

Applications

- SIP Emissions Inventory
- SIP TCM and CMAQ Reductions
- Conformity:
  - Plans (LRP)
  - Programs (TIP)



The left page shows the relationship of the course modules to the various analytical techniques that will be discussed.

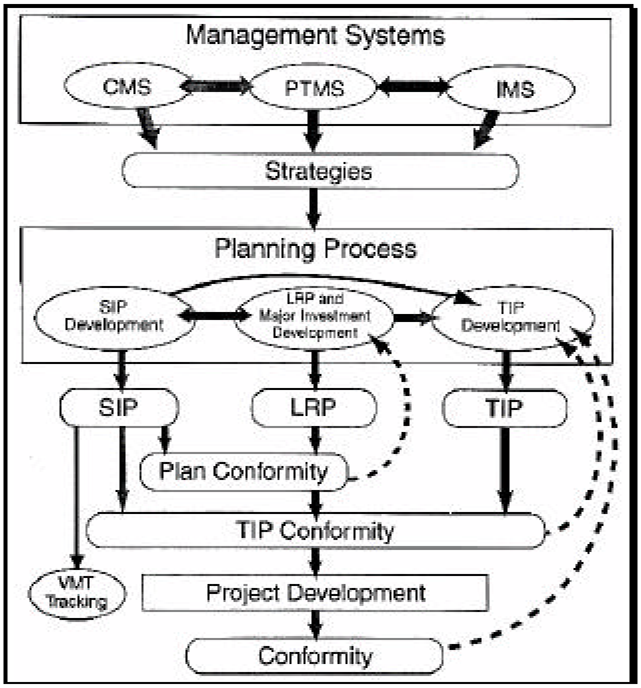
Each module includes a lecture and a manual workshop. The "TCM" module additionally includes a computer software package demonstration.

Application of Analysis Techniques

The analytical techniques discussed in this course will be applicable for various types of air quality analysis:

1. Development of mobile source inventories for the State Implementation Plan (SIP).
2. Estimation of emission reductions achievable from Transportation Control Measures (TCMs).
3. Conformity analyses for:
   a. Long Range Transportation Plans
   2. Transportation Improvement Programs (TIPs)

Connections Between Management Systems, Planning/Programming and Air Quality Conformity Processes



Relationship to Transportation Planning Process

The graphic on the left illustrates the relationship of the various air quality requirements (i.e. SIP development, conformity determination, and VMT and reasonable further progress (RFP) tracking) to metropolitan transportation planning requirements (i.e. long range planning, major investment analysis, transportation improvement program (TIP) development and the various management systems).

MODULE 1: TRAVEL DEMAND FORECASTING MODELS & LAND USE/ACCESSIBILITY ISSUES

Travel Forecasting Process

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Four-Step Process

TRIP GENERATION
TRIP DISTRIBUTION
MODE CHOICE
TRIP ASSIGNMENT
- Vehicle Volumes
- Transit Passenger Volumes

Introduction

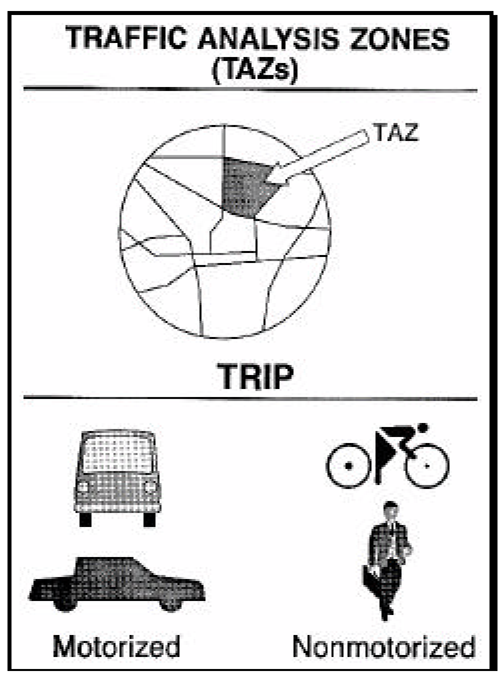
The presentation will cover:

1. What is current practice? It will not cover: How models are constructed, or details of how they work.
2. Implications for air quality analysis.
3. New requirements from EPA guidelines, including land use consistency checks.
4. Planned or on-going research to improve models.

Four-Step Process

The ultimate aim of the process is to estimate number of vehicles on highway networks and number of passengers on transit networks.

The first step is the only step which determines numbers of trips. In the next three steps, a fixed set of trips from step 1 are simply allocated -- among destinations, modes, or travel routes. Transportation system changes, in conventional models, only affect the allocation process, not numbers of trips i.e. "induced" trips cannot be estimated. Only a few MPOs have models which allow system changes to affect numbers of trips.



Basic Definitions

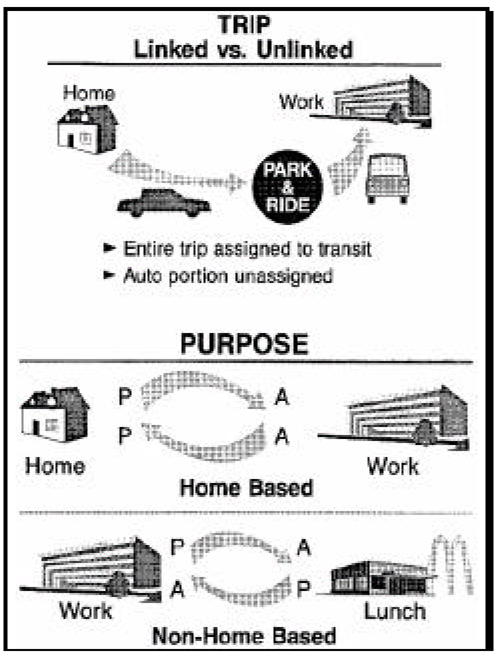
TAZs: Urban areas are split up into Traffic Analysis Zones.

Size of TAZ varies -- 1,000 - 10,000 people, on average. Depends on detail of network, and size of urban area.

Size of the TAZs in a region will affect the amount of "off- network" VMT that is not included in model output. With larger TAZs, more VMT will be "missing".

Trip: Only motorized trips are considered -- highway or transit, unless special studies are done. This is important to remember in analyzing travel reduction policies focused on shifting trips to non-motorized modes.

Linked trips: Only linked trips are considered. A trip where a person drives from home to a park-and-ride bus terminal, then rides the bus to work is one "linked" trip, but two motorized "unlinked" trips. For traffic forecasting, the whole (linked) trip is considered to be on transit, and the auto portion of the trip is ignored.



Trip Purpose: Trips may be home-based (HB) or non-home based (NHB). A home-based trip is one which has at least one end, either the origin or the destination end, in the home. Home based trips may be further categorized by purpose of the trip, e.g. work, shop, school, other etc. We are able to estimate home based trip characteristics better than NHB because we have better information on household characteristics.

Non-home based trips have neither end of the trip at home, e.g. a trip from work to lunch.

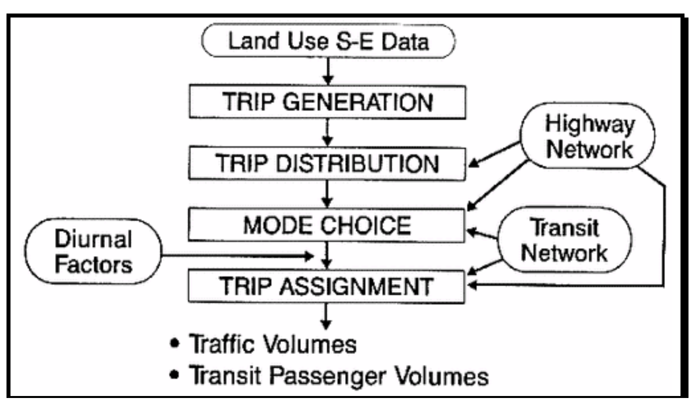
Productions/Attractions: Since home is what gives rise to travel, the home end of a HB trip is called the Production end. The Attraction end is the place the household member travels to, and back from. For NHB trips, the Production end is always the origin end and the Attraction end is the destination end.

Model Inputs

Overview of Four Steps

We will now provide an overview of the four models which comprise the four steps of the travel forecasting process, as well as their inputs and outputs.

The ultimate output of the four step process is a loaded network, i.e. a highway network



showing traffic volumes. The chain of models is run in order to forecast how traffic volumes will change with different policies.

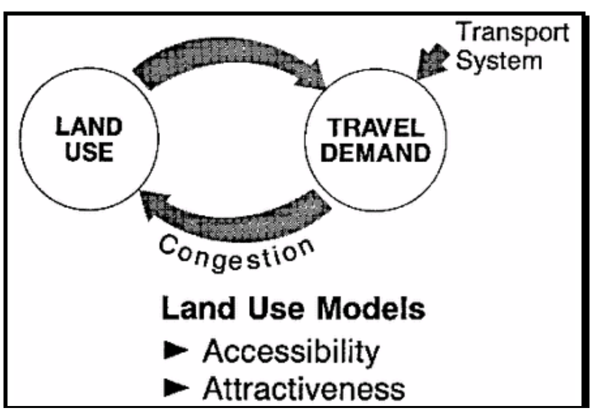
Trip generation forecasts the number of trips to be made. It is the only step of the process whose output does not generally change with transportation policy changes. For example, policies to change transportation prices generally have no effect on the numbers of trips output by trip generation models. (However, land use policies, e.g. changes in development densities, could affect numbers of trips output by some trip generation models.) The remaining models simply allocate those trips:

- Among various alternative destinations, in trip distribution.
- Among various alternative modes of travel (transit, solo-driver auto, carpools etc.) in mode choice.
- Among various alternative highway or transit routes in trip assignment.

The major inputs to the models are:

- Socio-economic characteristics of households and land use characteristics. They are used to estimate numbers of trips in trip generation, and mode of trips in mode choice.
- Highway networks. They are used to estimate travel times for use in trip distribution, mode choice and highway route choice.
- Transit networks. They are used to estimate travel times for use in mode choice and transit route choice.
- Time-of-day factors (or diurnal factors). They are used to split daily travel into various time periods -- generally a.m. peak, p.m. peak and off-peak.

Land Use Inputs



Forecasting Land Use Inputs

Estimates of future changes in population and employment within the TAZs of the metropolitan area are generally developed co-operatively by the Metropolitan Planning Organization and the various political jurisdictions which comprise it. Generally, no attempt is made to check whether land use assumptions are realistic in view of congestion on future highway networks which may be revealed from travel model forecasts.

A few MPOs have developed alternative future land use scenarios for testing with the travel models, to evaluate their impacts on the system.

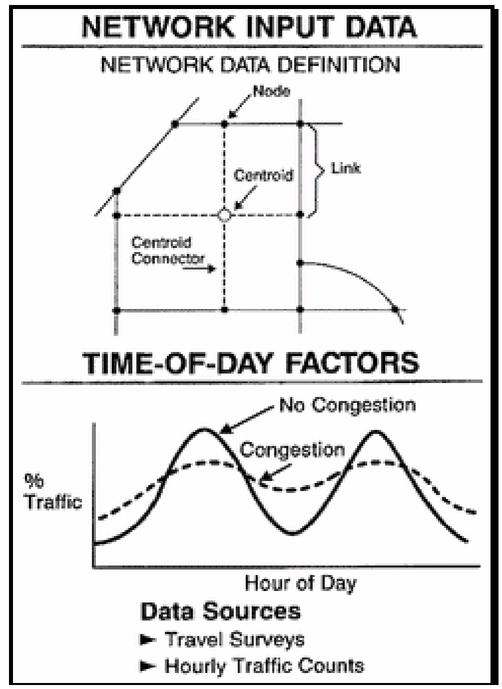
Occasionally, MPOs may use land use forecasting models to allocate future population and employment growth. Allocation is based on accessibility measures and attractiveness of each zone. Accessibility is measured by travel times and travel costs from the zone of interest to all other zones, and "attractiveness" reflects factors such as availability of good schools, environmental amenities etc.

Owing to relatively low travel costs, the "attractiveness" variable dominates most land use forecasting models. This reflects the fact that travel time is not as important as other factors when households and firms make location decisions.

Land use models are very data intensive and difficult to calibrate, and they have been found to be not very accurate. Therefore, it is not surprising that very few urban areas use these models.

Network Data

Only major roadways are generally represented on the highway network. Travel from a zone is assumed to originate at a single point called the centroid. Centroids are connected to the network by imaginary centroid connectors. Travel on these connectors, output from the model, represent part of the travel on local streets.



However, travel on local streets that occurs from one part of a zone to another (i.e. "intrazonal" trips) are not captured by the model, since those trips are assured to begin and end at the same point i.e. the centroid. This is a source of "missing" VMT, which must somehow be accounted for in air quality planning. We will discuss how to account for missing VMT in Module 3, Travel Model and Emission Factor Model Interactions.

Time-of-Day Factors

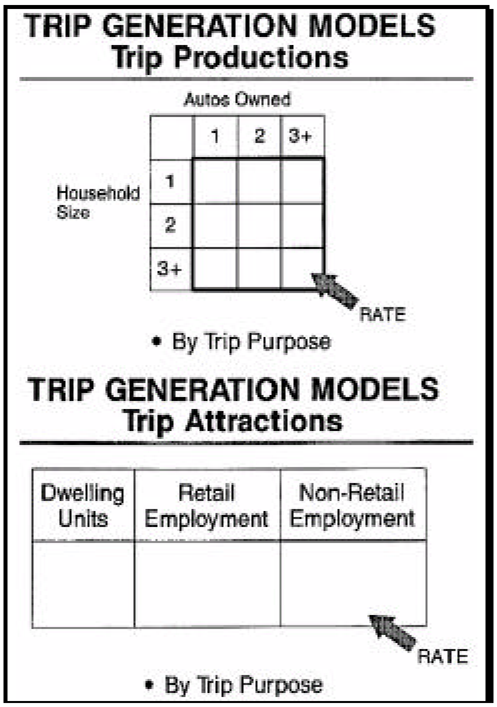
Generally, base year data is used to develop traffic by hour of the day as a percent of total daily traffic. These factors may be link based or trip based.

Link Based Factors: These are factors which may be applied based on facility class/area type and orientation of the link. They are derived from hourly traffic counts. Default factors may be obtained from NCHRP Report No. 187.

Trip Based Factors: The source of these factors is home interview travel survey data. From these data, percent of trips beginning during each hour can be determined by trip purpose. Default factors may be obtained from NCHRP Report No. 187.

It can be anticipated that future changes in level of congestion will affect percent of traffic in each hour. Increases in congestion causes spreading of the peak, and therefore a lowering of the peak hour percentage. Few MPOs have models which take peak spreading into consideration. Consequently, future peak hour volumes forecast by the models may be too high, speeds may be too low, and emissions estimates may therefore be affected.

Trip Generation: Productions

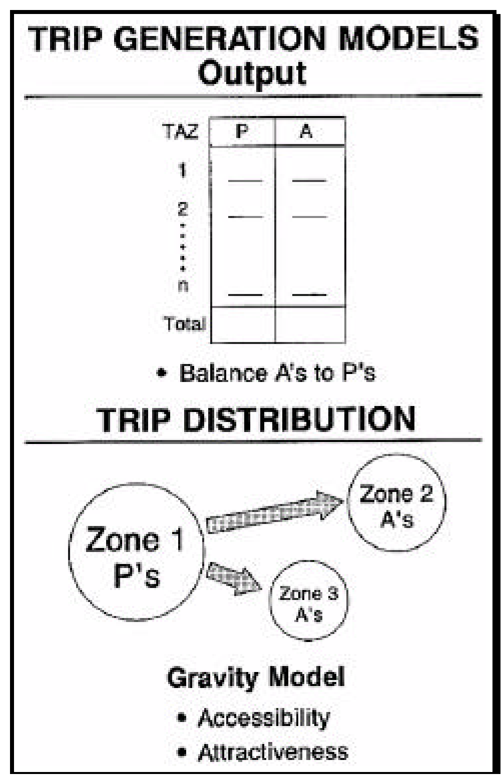


We will now briefly describe each of the four steps in the model chain. For more detail, we recommend attending FHWA's Travel Demand, Forecasting course offered twice a year in Washington, D.C., and several times each year out in the field.

Trip generation involves two types of models: Production models and Attraction models. They are developed for each trip purpose.

Production models are either cross-classification or regression models. They are based on household characteristics. Generally two or three characteristics are considered, e.g.

- income of household
- household size (i.e. number of persons)
- auto ownership



Trip Generation: Attractions

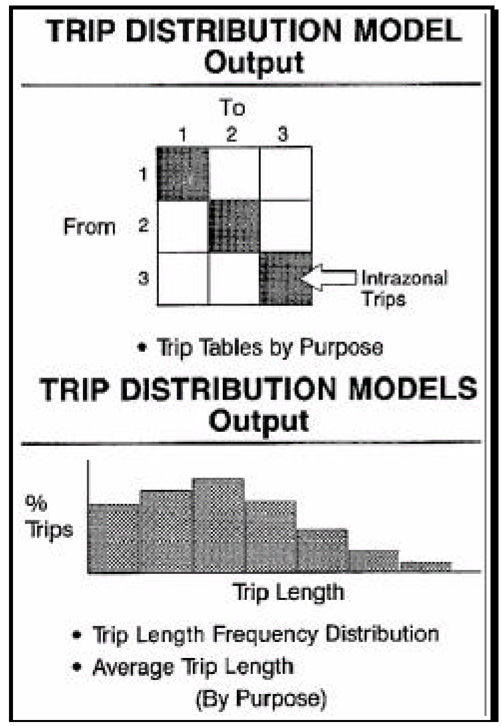
Attraction models are either rates or regression models. They are based on land use characteristics at the destination end of the trip, e.g. retail floor area; or socio-economic characteristics, e.g.

- trips per retail employee
- trips per non-retail employee
- trips per household

Balancing Trip Ends

After Productions and Attractions are generated by TAZ and aggregated to regional totals, they must balance. However, they generally don't balance, e.g. the number of total As may exceed or be less than total Ps. Since we have less confidence in our Attraction models and data, we adjust As in each TAZ by applying a factor based on the ratio of total Ps to total As.

Trip Distribution



Trip distribution is generally done using a gravity model which is based on a loose analogy to Newton's law of gravity, i.e. the pull of gravity is related to the masses and the distance between bodies.

The masses are the Productions and Attractions for each zone. Rather than distance, we use travel time between zones. Travel times are derived from highway networks, and converted to accessibility factors (also called friction factors).

Since people are willing to travel further for some purposes (e.g. work), accessibility factors vary by trip purpose.

Generally, base year travel times are used to derive accessibility factors, even for future trip distribution. If future levels of congestion will be different from base levels, the use of base times is inappropriate. EPA guidance calls for consistency between travel times on the network after assignment and the travel times used in trip distribution. To get consistency, travel times from assignment need to be fed back into trip distribution, and the process repeated until there is a reasonable match between trip distribution input times and assignment output times.

Gravity Model Output: Trip Tables

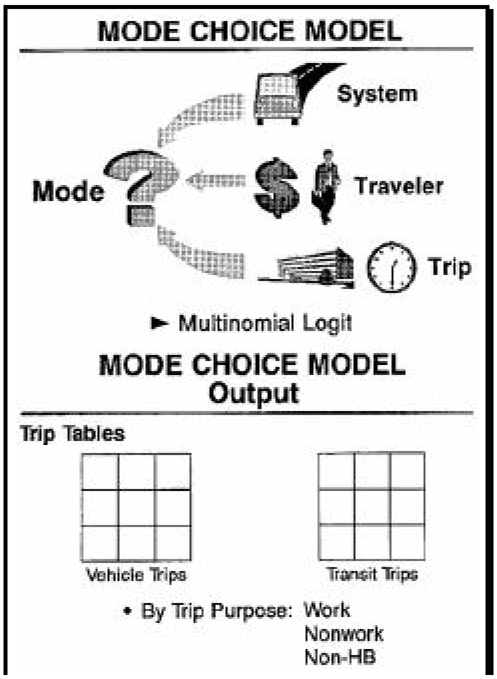
The output of the gravity model is a trip table for each trip purpose, which shows trips made from each zone to every other zone in the metropolitan area. The trip tables are generally collapsed into three (work, non-work, NHB) for input into the next step, mode choice.

Gravity Model Output: TLFDs

If requested, software packages can produce Trip Length Frequency Distributions (TLFDs) by trip purpose, which can be useful in air quality analysis. TLFDs are developed from trip tables and a corresponding matrix of zone-to-zone travel times. Basically, trips are categorized into various trip length categories and aggregated for each category to get the percentage in each category.

One input to the MOBILE emissions model is a trip length frequency distribution whose trip length categories are ranges of 10 minutes each, i.e. 0-9 min., 10-19 min. etc.

Mode Choice



Mode choice models are generally multinomial logit models. It should be noted that many urban areas do not have mode choice models. They may either "directly" generate auto and transit person trips during the trip generation step, based only on land use/socio-economic variables. Alternatively, they may simply assume a percentage share of trips on transit for each trip purpose, based on base year data. They then subtract transit trips from the trip tables to get automobile person trips. Auto person trips are then divided by an auto-occupancy factor to get vehicle trips.

Mode choice models are based on:

- System characteristics, e.g. travel times and costs
- Attributes of the traveller, e.g. income, family size, auto-ownership
- Attributes of the trip, e.g. purpose of trip, time of travel.

Mode Choice Model Output

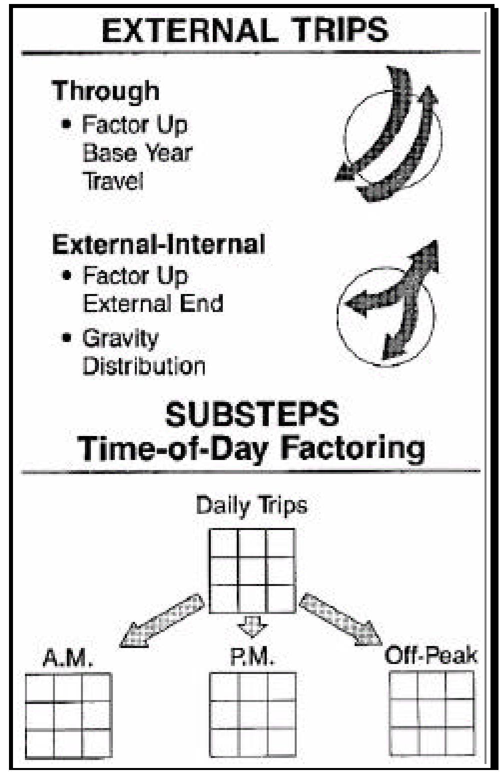
The output from mode choice consists of trip tables by purpose and mode (auto and transit).

Sub-steps: External Trips

Before the next step of the process, there are several sub-steps that are generally needed:

1. External-external (or through) trip tables must be developed. They are generally factored up from base year through vehicle trip tables using a growth factoring process called "Fratar" trip distribution.

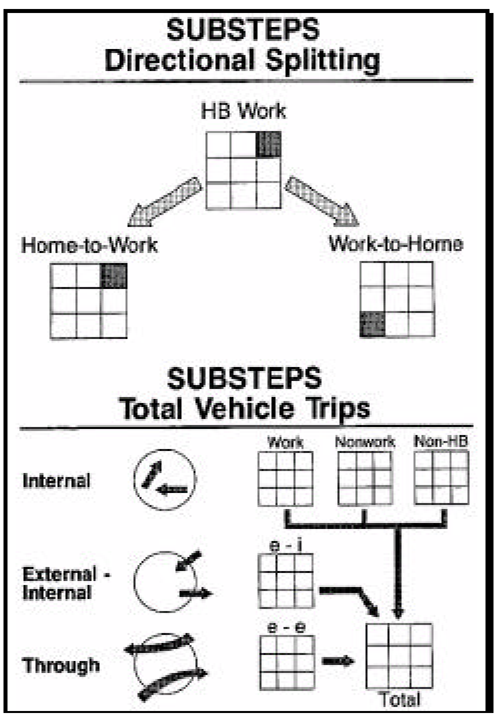
2. External-internal vehicle trip tables (i.e. trip tables with one end inside the urban area and the other outside) must be developed. They are generally developed from forecasts of future traffic at entry points into the urban area, internal trip ends based on land use/socio-economic characteristics, and gravity model trip distribution.



Sub-step (contd.): Time of Day Factoring

3. Time-of-day factoring must be done if traffic forecasts are desired by time of day. Factors reflect the proportion of daily travel, by trip purpose, that occurs during various time periods e.g., a.m. peak, p.m. peak and off peak. Factors are generally based on observed proportions from travel surveys.

Sub-steps (contd.): Directional Distribution

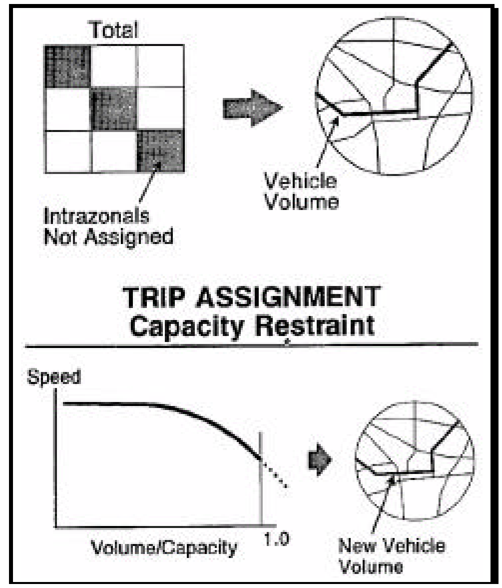


4. Conversion to directional trips must be done for HB trip purposes. For daily trip tables, a 50-50 split by direction is assumed. If trip tables are for specific time periods, splits must be based on travel survey data, e.g. what proportion of a.m. period H.B. work trips were going to work versus returning home?

Sub-steps (contd.): Total Vehicle Trip Table

5. Prior to trip assignment, all vehicle trip tables are generally combined into a single vehicle trip table. At this point, we lose the ability to use any information about vehicle type or mode of operation (i.e. cold start/ hot start/ hot stabilized) that may have been available (e.g. from auto log surveys) by trip purpose.

Network Assignment



Assignment of trip tables to networks is based on minimum time paths. Highway assignments are capacity restrained. Transit assignments are not.

Only interzonal trips are assigned. Intrazonal trips are not assigned to the highway network. Intrazonal travel is assumed to occur on local streets which are not part of the network used in the modeling process.

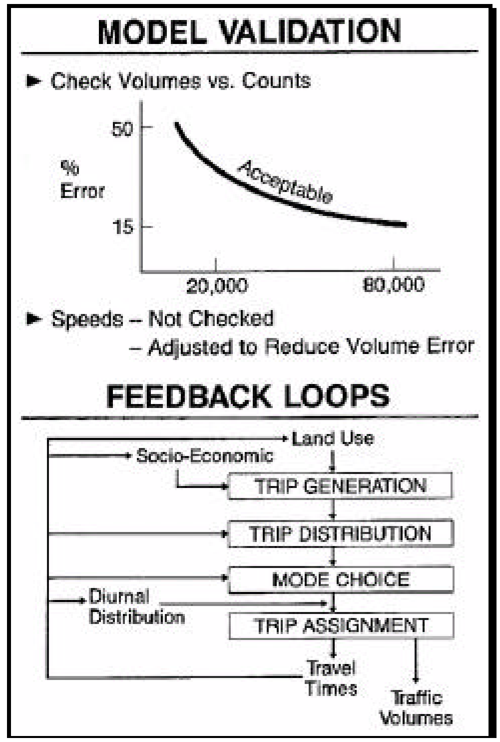
Capacity restrained assignments are iterative i.e. trips are assigned to shortest time paths, volume-to-capacity (V/C) ratios resulting from the assignment are computed, link speeds on the highway network are revised based on the computed V/C ratios, and trips are then re- assigned based on the revised speeds and minimum time paths.

Capacity restraint assignment can be done in one of three ways:

1. Incrementally, by assigning only part of the trip table in the first iteration and the remaining parts in each succeeding iteration.
2. Performing several iterations of full trip table assignment and averaging the results.
3. The most commonly used technique for capacity restrained highway assignment is the equilibrium procedure. It attempts to balance traffic along various alternative routes such that a traveller would not be able to reduce his travel time by shifting to a different route.

Model Validation

It is important to note that assignments are checked for accuracy by comparing traffic volumes -- assigned vs. counted. No attempt is made to check speeds or travel times on the network against observed speeds. In fact, input network speeds are often adjusted for the sole purpose of getting better comparisons of traffic volumes.



Feedback

Because the models are applied in sequence, there may be inconsistencies between travel time inputs into earlier steps of the process and the final travel times after highway traffic assignment. Most urban areas do not have feedback loops from traffic assignment back to the earlier steps. (A few areas feed back travel times from assignment into mode choice). There are many potential feedback loops:

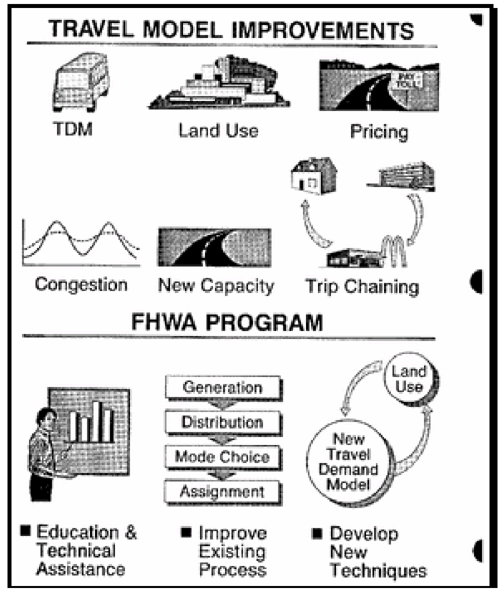
- Time-of-day distribution of travel--affecting shifts from peak to off-peak periods.
- Mode choice--affecting shifts to other modes
- Trip distribution--affecting choice of destination
- Trip generation--affecting decisions to own more automobiles, which impacts decisions to make motorized trips.
- Land use--affecting accessibility and therefore choice of location of households and firms.

Research on Model Improvements

Travel model improvements are a high priority research area at FHWA. Model improvements are needed not just for air quality analysis needs, but also to address and analyze other important urban transportation issues and policies, e.g.

- travel demand management policies
- growth management/ urban form/ urban design policies
- peak period or congestion pricing

- impacts of congestion on spreading of peak travel, and on urban development patterns
- assessment of the impacts of additional highway capacity on travel demand
- changing travel behavior patterns, e.g. trip chaining.



FHWA Research

FHWA's model improvement program* is progressing along three tracks:

- an on-going education, training and technical assistance program aimed at insuring proper usage of existing modeling techniques.
- enhancement of existing modeling techniques to respond to the issues discussed above.
- development of new modeling techniques, perhaps redesigning the entire forecasting process, including improved integration of transportation and land use analysis.

* The Environmental Protection Agency has provided partial funding for this program.

Summary

Concerns:
- Accuracy of Volumes
- Accuracy of Speeds
- Missing VMT
  - Intrazonal
  - Drive to P/R Lot
- Level of Detail
  - Not Hourly
  - No Vehicle Mix
  - No Hot/Cold Starts

Conclusions

The four step travel demand forecasting process was developed for purposes other than air quality analysis. Therefore, the process is not entirely compatible with the needs of air quality analysis. The models can be improved, but incompatibilities will remain, primarily:

- Levels of accuracy: The main purpose of the models as currently used is to assist in developing long-range transportation plans and sizing highway facilities. Error tolerance is high for this purpose, since errors can range from 15% to 50% (depending on facility class and traffic volume) without a change in the number of lanes needed. Model improvements may reduce error levels somewhat, but accuracy will still not be compatible with levels of accuracy assumed by air quality modelers, specially speed data.

- Level of detail: For accurate emissions modeling, detailed information from the highway network is needed, which is beyond the capability of even improved models. For example, emissions models need detailed data on travel by vehicle type, time-of-day, cold start/hot start, park duration, speed, local street travel, etc. Even improved models will probably not be able to provide accurate information to the level of detail needed.

Module 1: Travel Demand Forecasting Model Workshop

The Context:
Section 51.452(b)(1)(iv) of EPA's Transportation Conformity Final Rule states "Zone-to-zone travel times used to distribute trips between origin and destination pairs must be in reasonable agreement with the travel times which result from the process of assignment of trips to links. Where use of transit currently is anticipated to be a significant factor in satisfying transportation demand, these times should be also used for modeling mode splits;" The rule makes this an explicit requirement for serious, severe, and extreme ozone nonattainment areas and serious carbon monoxide areas after January 1, 1995. (Note that moderate CO nonattainment areas that have not reached attainment by December 31, 1995 are "bumped-up" to the serious category.)

The Assignment:
There are 673 traffic zones in the Baltimore, Maryland Travel Demand Forecasting Model System. A list containing the twenty zones with the highest number of households and the twenty zones with the highest levels of total employment was developed. The average travel times used as input for trip distribution from these 40 zones to all other zones were recorded. Additionally, the average travel times from these 40 zones to all other zones after traffic assignment were recorded.

As the urban planner for the Baltimore region you are asked to consider the following:

1. Are the differences between the distribution input travel times and the post assignment travel times for these zones sufficient to warrant rerunning the travel demand forecasting models with the post-assignment travel times as inputs to trip distribution.
2. How will VMT estimates change? Why?
3. If the models were rerun would the results be more accurate than the base run? Why?

Given: Area Map, Data, and Graphs of the Travel Times Before Distribution and After Traffic Assignment.

This assignment will be done in groups. Each group should chose one spokesperson to present the their findings to the class at the end of this workshop.

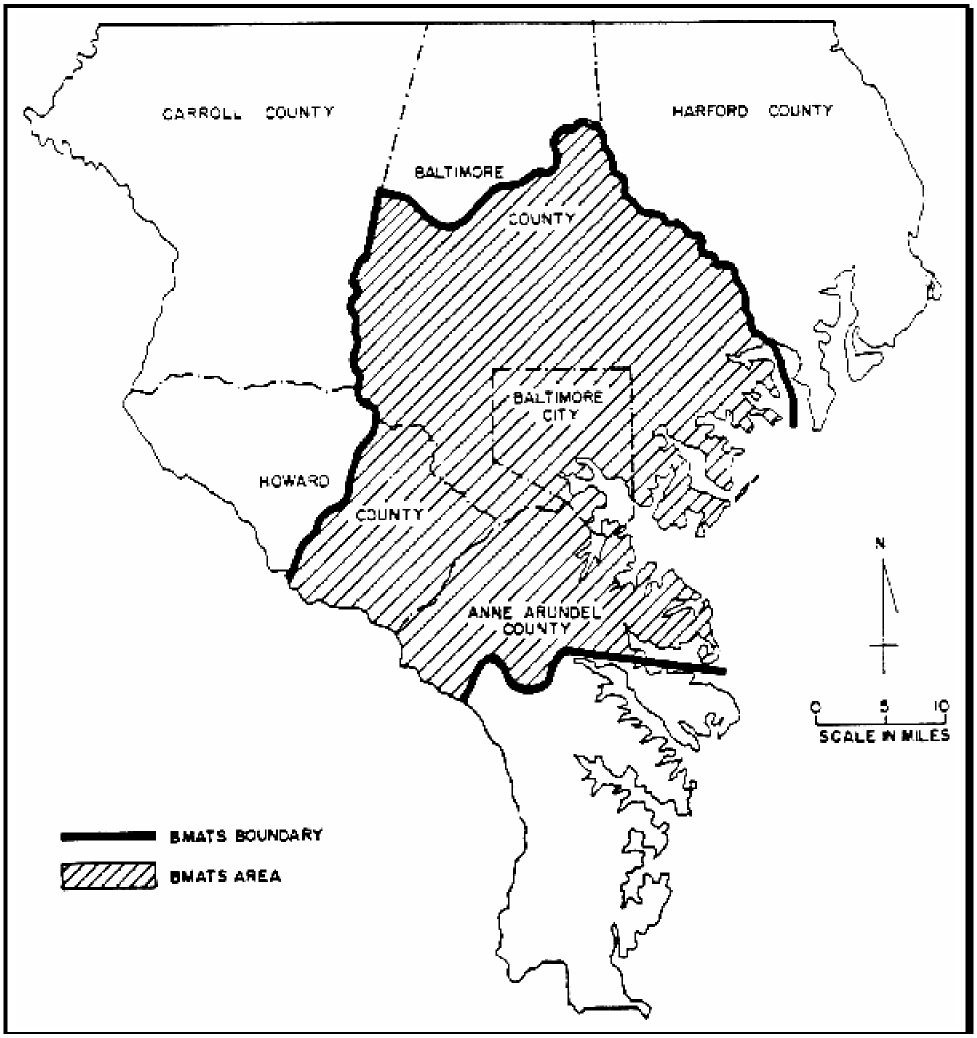


Figure 1: Baltimore Region and BMATS Simulation Areas

Zones with the Highest Number of Households

Zone	Before (mins)	After (mins)	Difference TT	% Change TT	Households
281	15.20	23.87	8.67	57%	10910
257	19.89	30.51	10.62	53%	10510
262	16.44	24.40	7.96	48%	12580
237	19.04	27.59	8.55	45%	11160
199	17.45	23.46	6.01	34%	10900
413	19.00	25.48	6.48	34%	11310
492	15.55	20.78	5.23	34%	11050
82	14.84	19.46	4.62	31%	9820
85	13.88	18.07	4.19	30%	9930
244	16.17	20.87	4.7	29%	15350
345	15.48	19.95	4.47	29%	12410
48	13.04	16.63	3.59	28%	9680
256	18.95	23.80	4.85	26%	10530
579	15.55	19.36	3.81	25%	12030
71	12.29	15.22	2.93	24%	10170
73	13.41	16.40	2.99	22%	10010
574	16.39	19.11	2.72	17%	9760
534	12.63	14.46	1.83	14%	9770
564	16.45	18.51	2.06	13%	10250
568	14.28	15.59	1.31	9%	10750

Zones with the Highest Employment

Zone	Before (mins)	After (mins)	Difference TT	% Change TT	Employees
274	15.24	23.10	7.86	52%	9520
286	11.07	16.49	5.42	49%	22310
262	16.43	24.36	7.93	48%	34880
630	17.78	24.47	6.69	38%	10870
384	13.85	18.66	4.81	35%	9360
215	18.57	24.98	6.41	35%	11430
448	15.60	20.97	5.37	34%	13130
603	15.24	20.24	5	33%	10540
389	15.11	19.37	4.26	28%	11520
144	11.96	15.33	3.37	28%	12360
114	15.52	19.80	4.28	28%	9000
387	15.20	19.10	3.9	26%	10870
391	14.41	18.10	3.69	26%	14150
121	16.76	21.04	4.28	26%	10990
118	15.93	19.90	3.97	25%	21530
343	20.07	25.06	4.99	25%	22780
117	17.16	21.14	3.98	23%	12280
132	14.93	18.33	3.4	23%	13880
523	21.45	25.08	3.63	17%	10640
582	14.87	16.31	1.44	10%	20740

TT = TRAVEL TIME

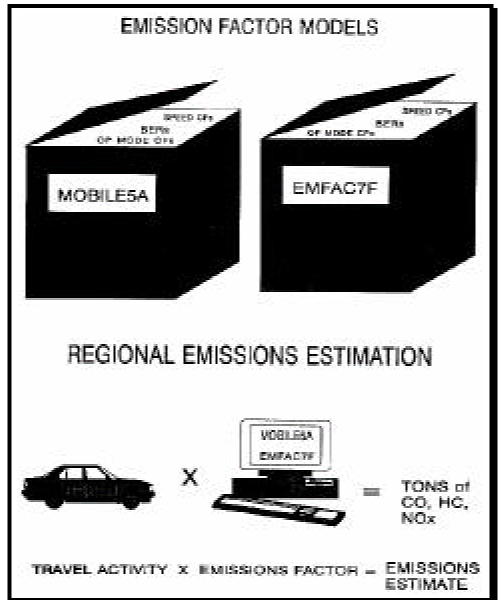
(mins) = MINUTES

% CHANGE = PERCENT CHANGE

Travel Times Before Distribution and After Assignment

MODULE 2: MOBILE SOURCE EMISSION FACTOR MODELS AND TRAVEL RELATED DATA REQUIREMENTS

Introduction



Travel demand forecasting (TDF) models are often viewed as "Black Boxes" by those in the air quality planning field. They know that data goes in and estimates of travel are output, but are often puzzled by what happens within the modelling process. Unfortunately, emission factor models have also been seen as a mysterious "Black Boxes" by many transportation professionals. The purpose of this module is to provide insight concerning what travel data is needed and how it is used in the air quality analysis process. The intent is to remove some of the mysteriousness of the emission factor models by opening the lid to the "Black Boxes" and viewing some of the models' components. Emission factor models, like TDF models, are very complex and not every aspect of the models will be addressed in this course. However, the basic structure of emission factor models will be discussed and some insights into how travel related parameters are used within the models will be provided. The discussion will focus on the following transportation related parameters:

- Trip length Distribution
- Operating Mode Mix
- Average Travel Speed
- Vehicle Miles Travelled Mix Fractions

Estimating Regional Emissions from On-Road Mobile Sources

The methodology for estimating emissions from on-road mobile sources was discussed in Module 1 of this course. The emissions estimation process can be represented by the simple equation shown below:

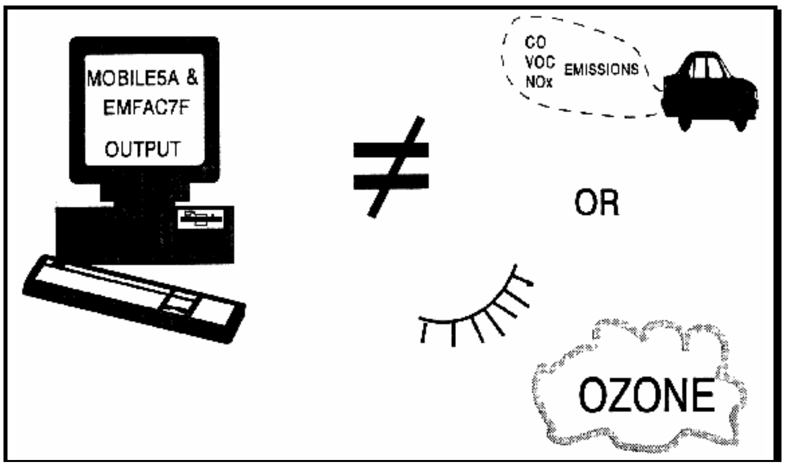
Travel Activity	X	Composite Emission Factor	=	Emissions
VMT (miles)		(grams/mile)		(grams)
Trips		(grams/trip)		(grams)

This module will focus on the second term of the equation, composite emission factors.

NOTE: Emissions estimates developed in units of grams can be converted to short tons by dividing 908175.

Emission Factor Control Misconceptions

Misconceptions About Emission Factor Models

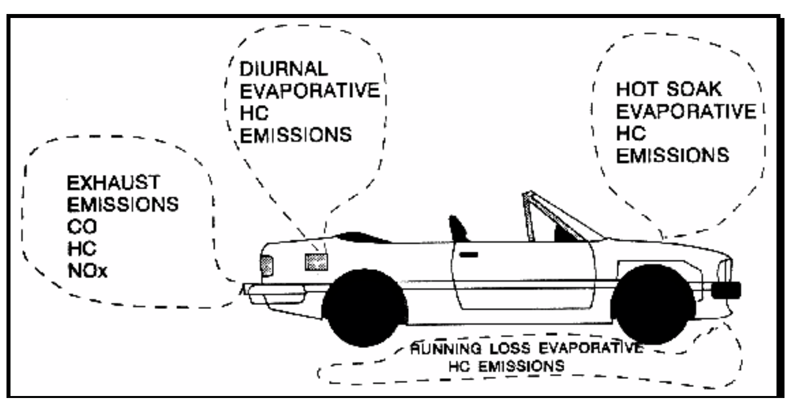


1. The output from an emission factor model is NOT pollutant emissions. Neither MOBILE5A or EMFAC7F is capable of providing an estimate of the quantity of emissions produced by on-road motor vehicles for any pollutant. The models only produce a set of composite emission factors with units of grams/mile or grams/trip.
2. Neither MOBILE5A or EMFAC7F can produce emission factors for ozone. Ozone is formed in the earth's atmosphere through a series of chemical reactions involving hydrocarbons and oxides of nitrogen in the presence of sunlight. Regional ozone concentration levels can be estimated through the use of photochemical dispersion models such as the Urban Air Shed model.

Hydrocarbons and oxides of nitrogen are considered ozone "precursors" because of their role in its formation. The function of these models in the ozone analysis process is to produce emission factors for HC and NOx which are used to estimate the quantity of the ozone precursors that is emitted from on-road mobile sources.

Motor Vehicle Emissions

Motor Vehicle Emission Sources

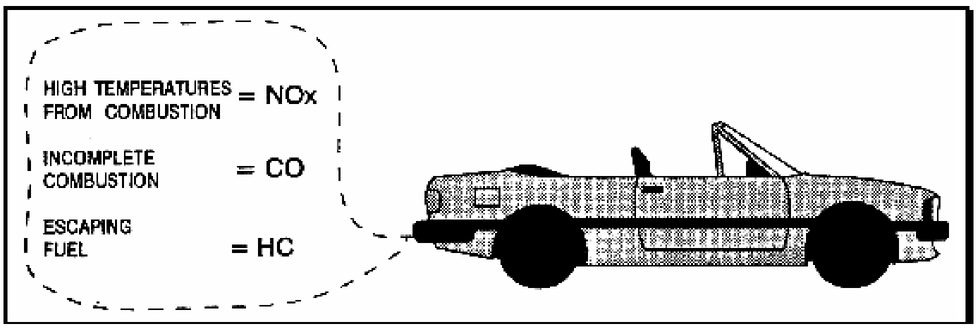


The three primary pollutant associated with motor vehicles (HC, CO, NOx) were described in Module 1. Developing quantitative estimates of these pollutants requires an understanding of how they are produced. These pollutants can be linked to two fundamentally different emissions producing processes and two different motor vehicle systems:

-- Combustion	-- exhaust system
-- evaporation	-- fuel storage and delivery system

Most people readily associate air pollution with the motor vehicle exhaust system because they have seen and smelled the fumes exiting their vehicle. However, to fully account for the emissions that result from on-road motor vehicles one must also develop estimates of the quantity of hydrocarbons that evaporate into the atmosphere from the fuel storage and delivery system.

Motor Vehicle Emissions - Exhaust Emissions



Exhaust emissions are commonly referred to as "tail pipe" emissions. Carbon monoxide, Oxides of Nitrogen, and Hydrocarbon emissions are all products of the combustion of fossil fuels within a vehicle's engine. However, each pollutant is produced in a different manner. Various compounds of nitrogen and oxygen are formed as a result of the high temperatures associated with combustion. Carbon monoxide is a by- product of the combustion process and actually results for the incomplete combustion of the organic fuels. Finally, the hydrocarbon emissions result from the unburned portion of the fuel that escapes through the exhaust system of the vehicle.

Operating Mode

The operating mode of on-road motor vehicles is important because exhaust emissions vary significantly depending of which operating mode the vehicles in. The following are the three operating modes considered for light duty vehicles:

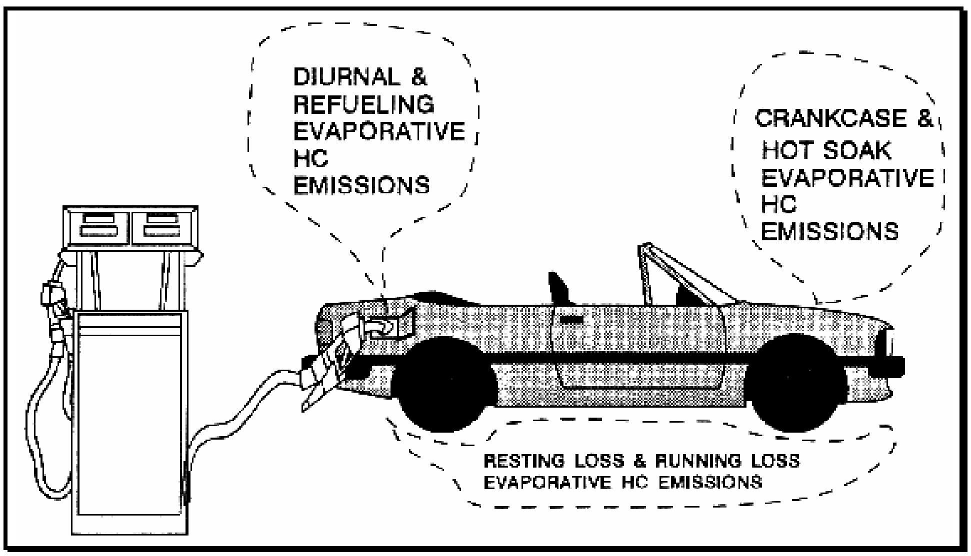
- Cold Start
- Hot Start
- Hot stabilized

The start modes include the first few minutes of operation after a vehicle's engine has been started. This difference between a cold start and a hot start is the length of time that the engine is shut off before being restarted. The hot stabilized mode includes all the time that a vehicle is in operation except for the start mode periods.

The differences in emission quantities between operating modes are primarily due to two factors: the fuel-air mixture and the emissions control equipment. HC and CO emissions are highest during the cold start mode because the catalytic emission control systems do not provide full control until they reach operating temperature and a richer fuel-air mixture must be provided to receive satisfactory performance from a "cold" engine. The fuel mixture in the cold start mode has little effect on NOx emissions, however, the lack of fully operational emissions control equipment will provide elevated NOx during this mode. Emission rates for all three pollutants are less during hot starts than for cold starts and are lowest during hot stabilized operation.

Motor Vehicle Emissions - Evaporative Emissions

Evaporative emissions consist only of hydrocarbons. They escape from a number of locations in the fuel storage and delivery system in quantities that are highly dependent on temperature. The MOBILE model addresses the following 6 categories of evaporative emissions:



Hot Soak - Emissions from the carburetor or fuel injector occurring when the engine is turned off.

Diurnal - Results from the "breathing" of the gasoline tank due to temperature fluctuations over the 24-hours in a day.

Running losses - Emission losses that occur while the vehicle is being operated. They result when more fuel is emitted into the emissions control canister than is being purged from it.

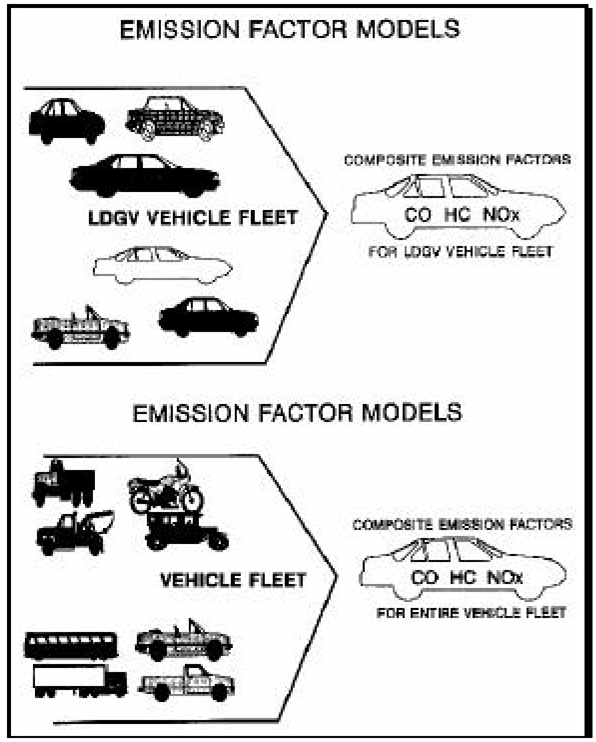
Resting losses - Emissions that result from vapor permeating the evaporative emission control system or from liquid fuel leaks.

Refueling losses - There are two components, vapor space displacement and spillage both of which occur while a vehicle is being refueled.

Crankcase emissions - Not true evaporative emissions, but are defined as those that result from defective positive crankcase ventilation valves.

NOTE: Diurnal, hot soak, and running loss emissions are a function vehicle travel, however, only running loss emission rates are directly impacted by the travel related inputs to MOBILE5A.

Emission Factor Models



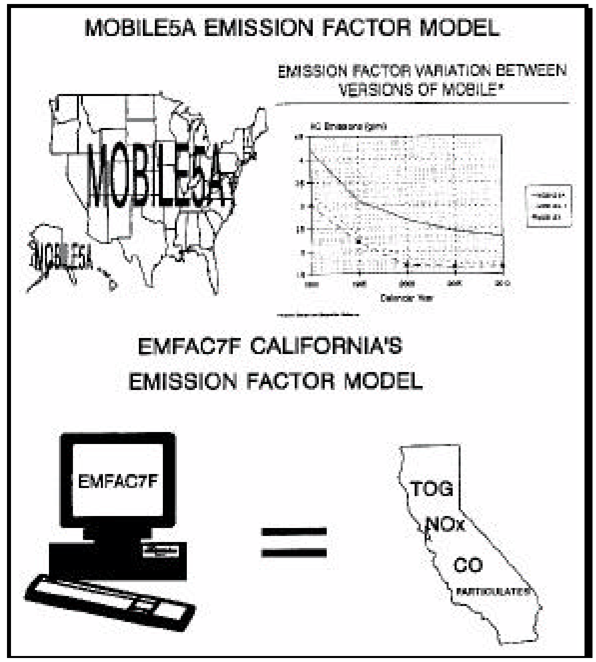
There are a number of travel demand forecasting software packages available for use in the United States and there is no Federal requirement to use a specific modeling package. However, the same can not be said for emission factor models. The U.S. Environmental Protection Agency permits the use of only two emission factor models MOBILE and EMFAC. The MOBILE model must be used in every state except California where the EPA permits the use of EMFAC.

The models were both developed based on the understanding that one cannot perform a regional mobile source emissions analysis based on each individual vehicle in the fleet. These models produce composite emission factors which approximate the emissions characteristics of the entire population of vehicles.

A separate composite emission factor is developed for each pollutant type (e.g. carbon monoxide, nitrogen oxide, and hydrocarbons). The composite emission factors are an approximation of the quantity of a particular pollutant that would be emitted by the "typical" or "average" vehicle in each vehicle classification. The MOBILE model develops a different set of emission factors for each of the years 1960 through 2020.

Emission Factor Models - Mobile

The MOBILE model was developed by and is maintained by the U.S. Environmental Protection Agency. It was initially developed as a policy testing tool to evaluate the impact of the motor vehicle pollution control standards. It has since been altered for use as an air quality planning tool for on-road motor vehicle emissions. The MOBILE model develops composite emission factors for the following pollutants:



- Hydrocarbons
- Carbon Monoxide
- Nitrogen Oxide

The MOBILE model is updated periodically to reflect both changes in the understanding of emissions and changes in U.S. law. As of this writing MOBILE5A is the current version of the model. The U.S. EPA usually requires the most recently released version of the model to be used in all analyses. It Is important for to note that emission factor values can vary dramatically from one version of the model to the next.

Emission Factor Models - EMFAC

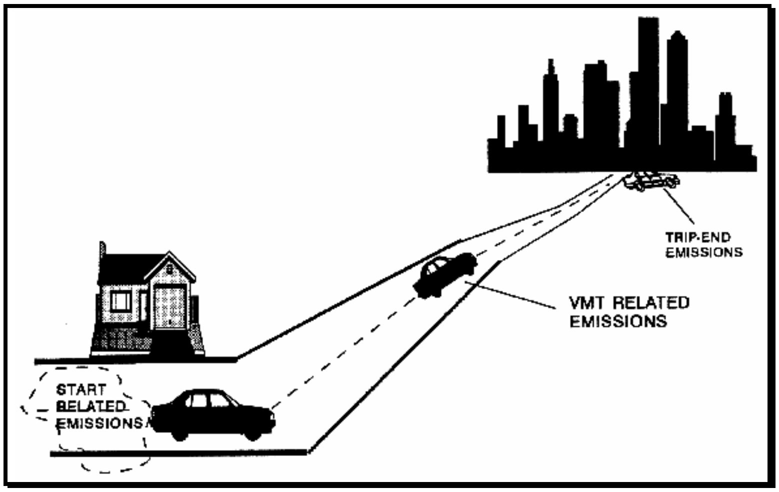
The California Air Resources Board (CARB) has developed and maintains its own emission factor model for use in the state of California. The model development was coordinated with the California Department of Transportation (Caltrans). The latest version of the model is EMFAC7F can be run on either a main frame or personal computer. EMFAC7F produces of composite emission factors for the following pollutants:

- Total Organic Gases(TOG)
- Carbon Monoxide
- Oxides of Nitrogen
- Particulate Matter

There is a slight difference between the components of total organic gas emissions and hydrocarbon emissions, however, for purposes of this discussion the terms will considered equivalent. EMFAC7F has the capability of producing both exhaust and evaporative emission factors for TOG. Additionally, the model can develop an emission factor for particulate matter that results from both exhaust and tire wear.

Differences Between Mobile and EMFAC

The basic structure of two emission factor models is similar. However, there are some significant differences between EMFAC7F and MOBILE5A in the way that emissions associated with a vehicle trip are allocated. For example, EMFAC7F produces separate emission factors for cold starts, hot starts, and hot stabilized vehicle operation. The start related emission factors have units of grams per trip and the stabilized factors are in grams per mile. On the other hand, the MOBILE model "spreads" the emissions from vehicle starts over the entire vehicle trip so that both start related emissions and stabilized exhaust emissions are estimated by a single emission factor with units of grams/mile. The differences in the models' structure affect the travel related data requirements and to some extent the flexibility of the models as analysis tools.

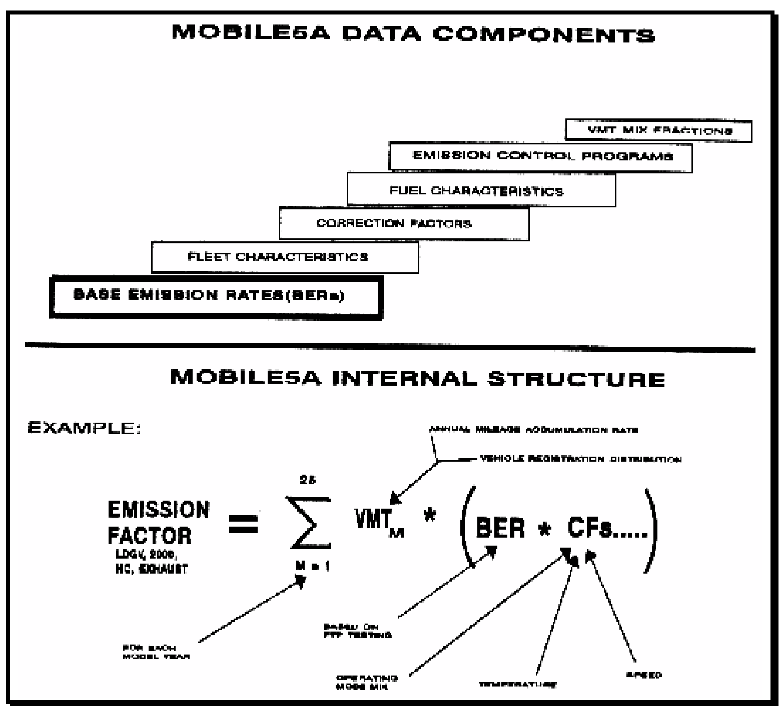


NOTE: Since every state except California is required to use the EPA's model the remainder of this module will be focused on MOBILE5A.

Emission Factor Model Components

The structure of the MOBILE model can be simplified to the following five core components:

1. Base Emission Rates (BERs)
2. Fleet Characteristics
3. Correction Factors
4. Fuel Characteristics
5. Emission Control Programs



The base emission rate is an idealized rate based on standardized vehicle testing that never occurs in the "real world". The other four model components are used to adjust the idealized rate so that it more closely represents the conditions under which vehicle emissions are actually produced. The relationship between these components and the fleet average emission factor for a vehicle class, calendar year, pollutant, and emission producing process (e.g. exhaust, evaporative) can be described by the following equation:

$$EF\_i,j,k = \sum_{m=1}^{n} VMTm * (BERj,k,m * CFj,k,m...)$$

Where:

EF_i,j,k = fleet-average emission factor for calendar year i, pollutant j, and process k (e.g. exhaust, evap);

VMTm = fractional VMT attributed to model year m (the sum of VMT, over all model years n is m unity)

BERj,k,m = base emission rate for pollutant j, process k, and model

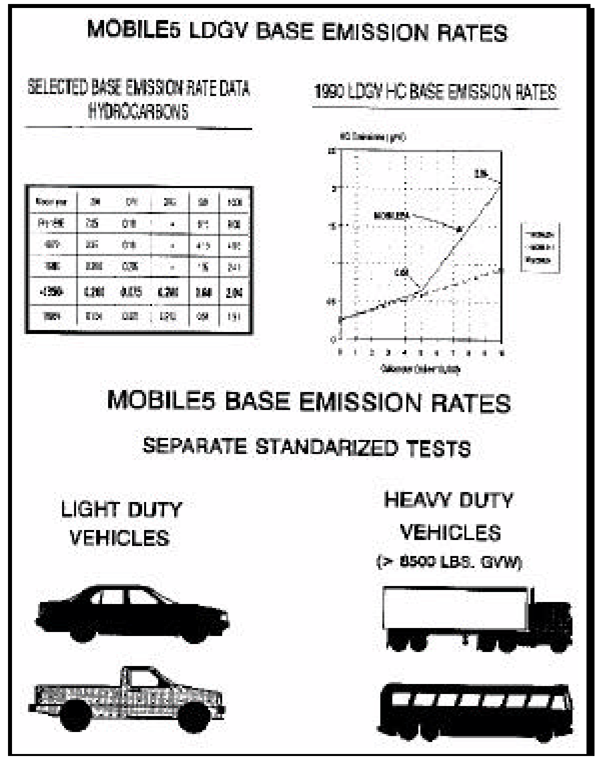
Cfj,k,m = correction factor(s) (e.g., temperature, speed) for pollutant j, process k, model year m, etc;

The same standard modelling approach is used to estimate emissions of HC, CO, and NOx from both exhaust and evaporative processes.
NOTE: Since only one component of evaporative emissions are impacted by travel parameters the remaining discussion of the components of emission factor models will focus primarily on exhaust emissions.

Emission Factor Model Components - Base Emission Rates (BERs)

The modeling approach used in emission factor models is centered around the base emission rates (BERs). The BERs consist of a zero mile emission rate, y-intercept, and a deterioration rate (DR), slope. More than one deterioration rate is used for some model years. These basic emission rates for each model year, pollutant type, and emission producing process are developed separately for the following eight classes of vehicles:

- Light duty gasoline vehicles (LDGV)
- Light duty gasoline trucks 1 (LDGT1)
- Light duty gasoline trucks 2 (LDGT2)
- Light duty diesel vehicles (LDDV)
- Light duty diesel trucks (LDDT)
- Heavy duty gasoline vehicles (HDGV)
- Heavy duty diesel vehicles (HDDV)
- Motorcycles (MC)



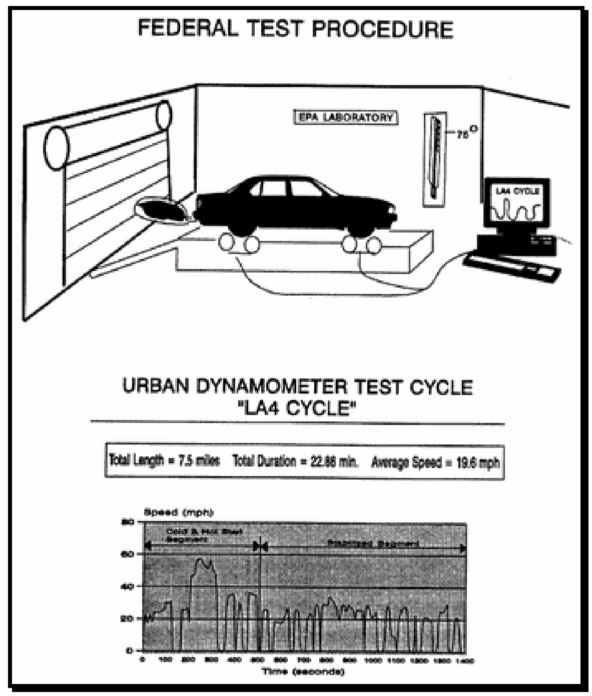
An example of the BER values contained in MOBILE5A is shown on the facing page.

The BERs are developed by operating a small number of vehicles over standard test cycles with tightly controlled conditions. The emissions produced during the testing are captured, measured, and then used as an approximation of the fleet wide average.

There are separate standardized tests for light duty vehicles and heavy duty vehicles (>8500 lbs. gvw). Due to the difficulty of testing full size heavy duty vehicles their tests are conducted only on the engines not the full vehicle as in the light duty test. The emission factors developed for the heavy duty vehicle engines are converted to a gram/mile basis so that they are comparable to light duty vehicle factors. The overall approach of testing the two groups of vehicles is similar. Therefore, the, remaining discussion of test procedures will focus on the those used for light duty vehicles.

Federal Test Procedure

The vehicles being tested under the FTP are placed on a chassis dynamometer and are operated over a standardized driving cycle called the Urban Dynamometer Driving Schedule (UDDS), or "LA4 Cycle." This test involves duplicating a speed-time profile from an actual road route driven in the Los Angeles area in the late 1960's. This driving cycle was designed to be representative of a typical urban driving pattern. The LA4 cycle is 7.5 miles in length and consists of 18 segments of non-zero speed (at varying engine loads) separated by periods of idling which result in an average speed of 19.6 mph. Due to the significant differences in vehicle emission rates for the three operating modes the FTP is divided into three distinct segments:



- A cold start portion consisting of the first 3.59 miles or 505 seconds of the UDDS
- A stabilized portion composed of the final 3.91 miles or 867 seconds of the UDDS
- A hot start portion which involves a second period of operation over the first 3.59 miles (505 seconds) after the vehicle's engine has been turned off for 10 minutes

The base emission rates resulting from tests conducted according to the FTP can be calculated based on the following formula:

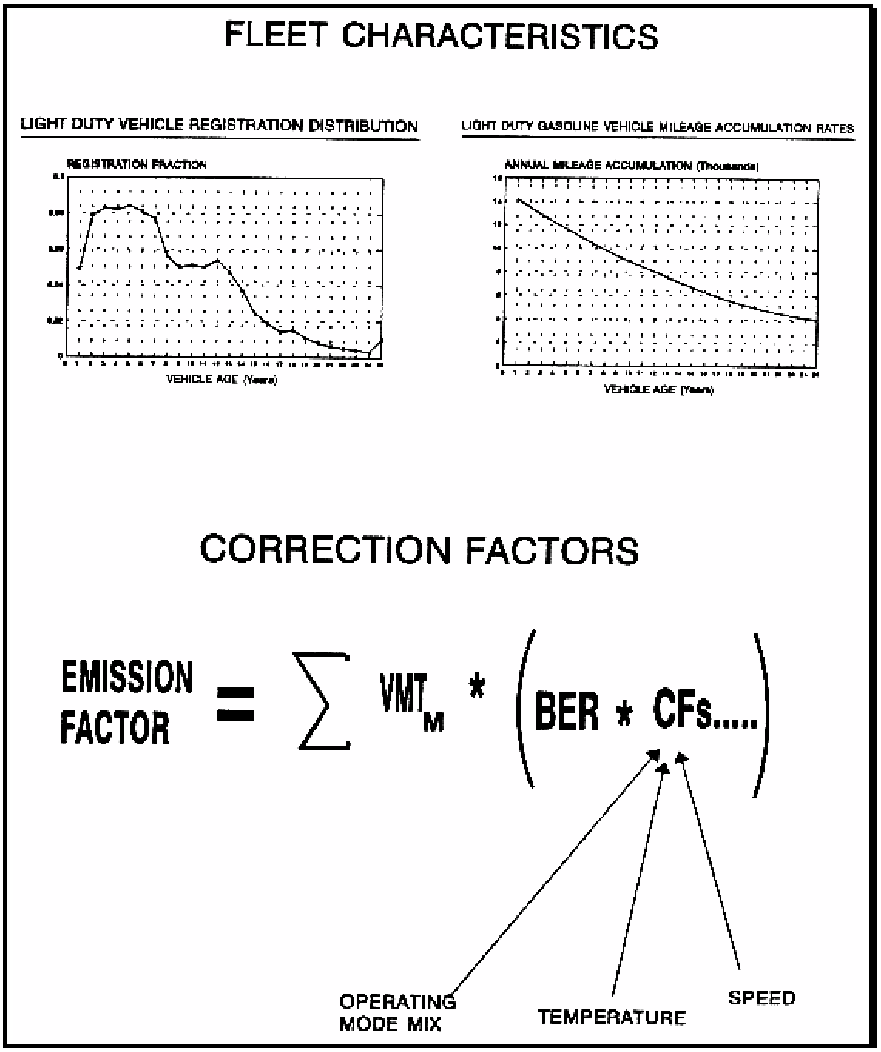
$$BER = \frac{3.59 * (0.43 * \text{cold start} + 0.57 * \text{hot start})}{7.5} + \frac{3.91 * \text{stabilized}}{7.5}$$

EPA assumes that 43 percent of all starts are cold starts and 57 percent are hot starts which accounts for the 0.43 and 0.57 terms in the equation. By division the equation can be reduced to the following:

$$BER = 0.206 * \text{cold start} + 0.521 * \text{stabilized} + 0.273 * \text{hot start}$$

Take note of the coefficients of the terms in this equation. They show up later in discussion as the default values for some of the operating mode mix inputs.

Emission Factor Model Components - Fleet Characteristics



The base emission rates characterize emissions for a specific model year vehicle fleet and vehicle class. The age distribution and the rate of mileage accumulation within each vehicle class can significantly effect the average rate of vehicle emissions. Additionally, the mix of travel between vehicle classes impacts the rate of emissions and must also be accounted for in the composite emission factors. MOBILE uses national average values for these parameters as defaults. However, the user has the option of employing data more representative of local conditions. MOBILE5A assumes that 25 model years of vehicles comprise the fleet. The following equation is used to calculate the VMT fraction for each of the model years:

$$\text{VMT } m = \frac{\text{REG } m \ * \ \text{MILES } m}{n}$$

ä (REG m *MILES m)

m=1

Where:

MILES m	=	annual mileage accumulation for each model year m
REG m	=	registration fraction for the model year m
n	=	total number of model years in fleet

Emission Factor Model Components - Correction Factors

The emissions tests which produce the BERs are performed under the same standard conditions. Thus, these base emission rates must be adjusted or corrected to be more representative of emissions that would result from vehicles operating under conditions different from those in the standard tests. Emission factors are developed by multiplying the BERs by a series of correction factors including temperature, operating mode, and speed. The actual calculations involved are complex but can be represented by the following equation:

EF = BER * TCF * OMCF * SCF

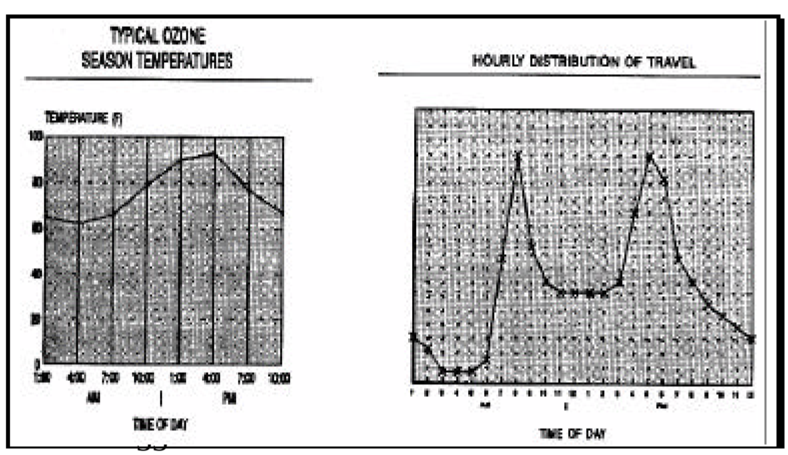
Where:

EF	=	emission factor(g/mi) corrected for operating mode, temperature, & speed
BER	=	composite FTP based emission rate (g/mi)
TCF	=	temperature correction factor
OMCF	=	operating mode correction factor
SCF	=	speed correction factor

Temperature Correction Factors
FTP Temperature Range = 68 TO 86 F

Temperature

Temperature is an important factor in determining the emission rates for all three pollutants being considered. The tests conducted under the FTP must be performed within a temperature range of 68ø to 86øF. For temperature outside this range the model applies correction factors to the BERs. The source and type of temperature data input into the model to be used in the correction factor calculations is usually specified by EPA. Obtaining temperature data and developing appropriate temperature profiles for a given mobile source analysis is



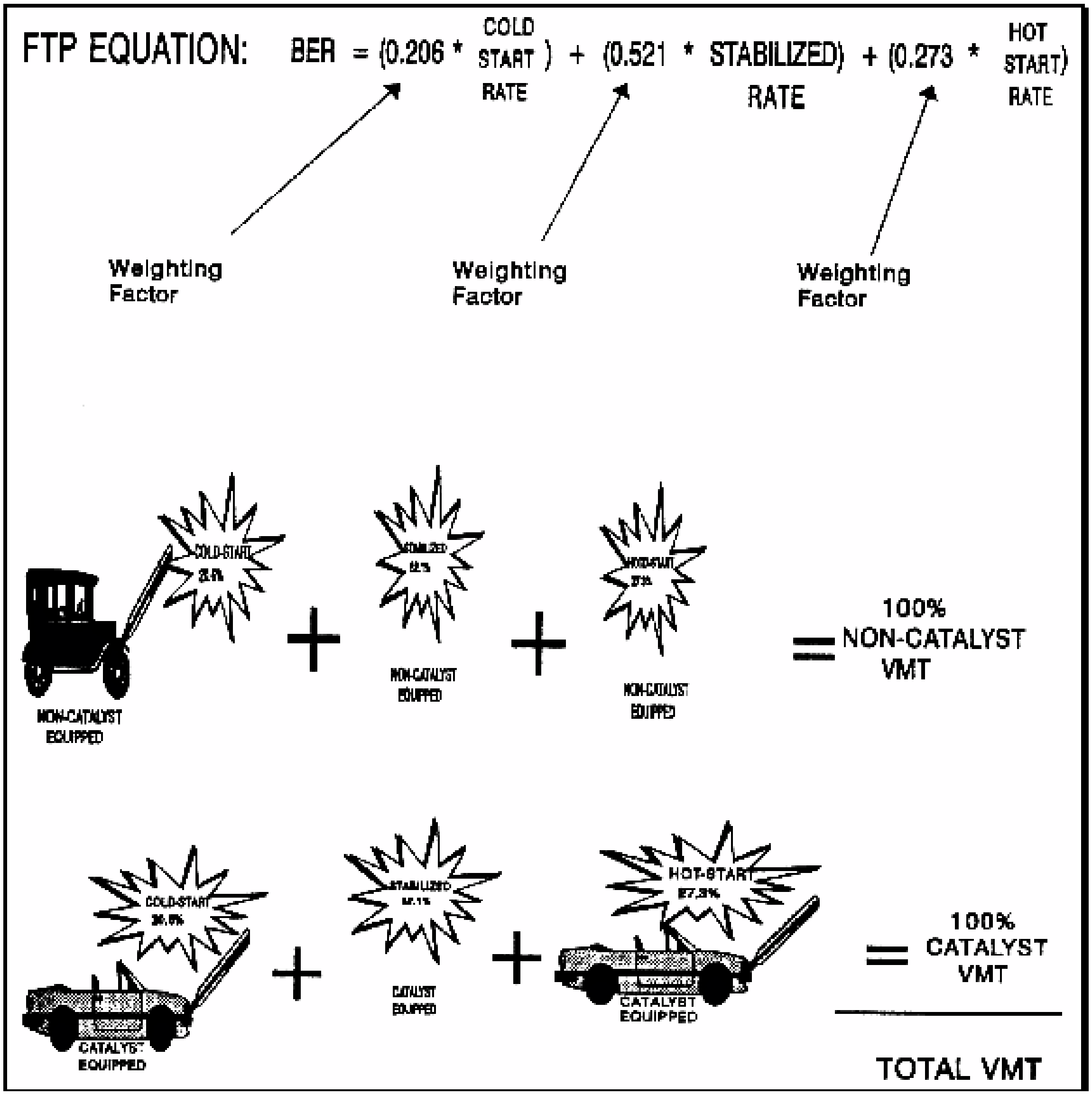
usually the responsibility of an air quality planner.

NOTE: Transportation professionals should check temperature inputs to the model to ensure that they are consistent with the temporal variations in travel data being used. For example, if the analysis is performed for three time periods such as daily, morning peak period, and afternoon peak period and a request is made for speed data representative of those periods then one should also expect different temperatures to be used for each period.

Operating Mode Mix Adjustments

Operating Mode Mix

As previously noted it is important to know the portion of the travel that occurs in each operating mode because exhaust emissions are highest just after the vehicle is started and are reduced significantly once the catalytic converter and engine warm up. MOBILE makes two operating mode related "adjustments" to the BERs - Bag corrections & Bag weight adjustments.



First, separate bag correction factors are used to alter the BER so that it more closely represents the vehicle fleet being modelled. These correction factors vary by pollutant type. The bag correction factors for the catalyst equipped vehicles are based on the vehicle mileage characteristics of the fleet. The user can not select these corrections, they are automatically made by the model.

Secondly, the BERs are adjusted by changing the weight of each bag. This adjustment is made by the user through altering the operating mode mix fractions. Vehicle technology type affects the amount of time required for a vehicle to warm up and "change" operating modes. Therefore technology type is also a parameter considered when developing the bag weights. MOBILE5A considers two vehicle technologies (catalyst and non-catalyst) when developing emission factors.

The MOBILE model needs the percent of the VMT travelled in each of the six technology type/operating mode combinations to properly adjust the BERs. However, the model assumes that the percent of miles travelled in the stabilized mode is the same for both technology types values so only the following three parameters are needed as input: the non- catalyst cold-start, catalyst hot-start, and catalyst cold-start percentages. The model calculates the values for the other three parameters internally.

The MOBILE5A default operating mode values are as follows:

Technology Type/Operating mode	**Default/Value**
Non-catalyst Cold-start	20.6%
Catalyst Hot-start	27.3%
Catalyst Cold-start	20.6%

NOTE: The MOBILE5A operating mode mix corrections apply only to light duty vehicles.

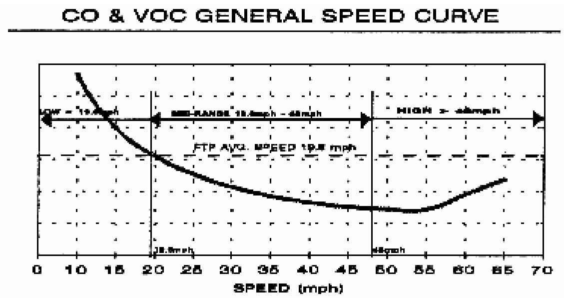
Mobile5A Average Travel Speed Curves

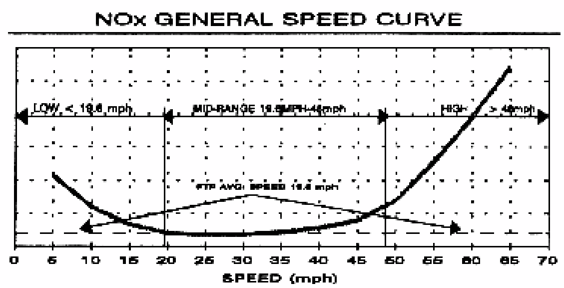
Average Travel Speed

The base emission rates used in the MOBILE model are developed under the previously described FTP procedures. At the core of the FTP is a 7.5 mile driving cycle (shown on facing page) which has an average speed of 19.6 mph. It is important to realize that the model actually calculates factors for a 7.5 mile trip with an average speed of 19.6 mph. The emission factor produced by the model for a given speed (i.e. 19.6 mph) is not the rate of emissions a vehicle would experience while traveling at that speed. It is an approximation of the average rate of emissions over a trip with an average speed of 19.6 mph.

It follows that the type of speed data used as an input to MOBILE5A is the "average travel speed" not spot speeds like one might collect for many traffic engineering applications. The 1985 Highway Capacity Manual defines average travel speed as the length of the segment divided by the average travel time of vehicles traversing the segment, including all stopped delay times.

When a user selects a speed other that 19.6 mph the model uses speed correction factors to adjust the base emission rates. The correction factors are based on a series of driving cycles each with a different average speed. There are actually three speed correction regimes considered in MOBILE: low speed (under 19.6 mph), mid-range (19.648 mph), and high-speed (48 to 65 mph). Thus with the selection of a speed the model's user is actually selecting an emission rate for a driving cycle with that average speed.



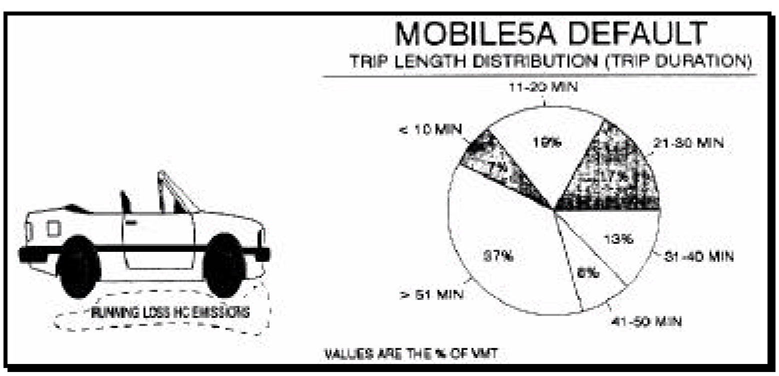


Both exhaust and running loss evaporative emission factors vary significantly with the average speed assumed. Examples of the general relationship between speed and MOBILE's emission factors for each HC and CO are shown on the facing page.

Trip Length Distribution Evaporative Emissions Correction Factor

Trip Length Distribution

The phrase trip length distribution as used pertaining to MOBILE5A could be misleading to transportation planners. The phrase actually refers to the DURATION of the trip in this context. A region's trip length distribution is important when using MOBILE because of the impact trip duration has on running loss emissions. Running losses are the portion of evaporative HC emissions that escape from the fuel system and engine as the vehicle is being operated. The EPA has determined that the quantity of running loss emissions is a function of the time that a vehicle is in operation. Emissions increase significantly as the duration of the trip increases and the fuel lines, fuel tank, and engine become heated. The trip length distribution as defined in MOBILE5A affects ONLY the running loss portion of evaporative emissions not exhaust emissions.



The default values for each trip duration category is shown below:

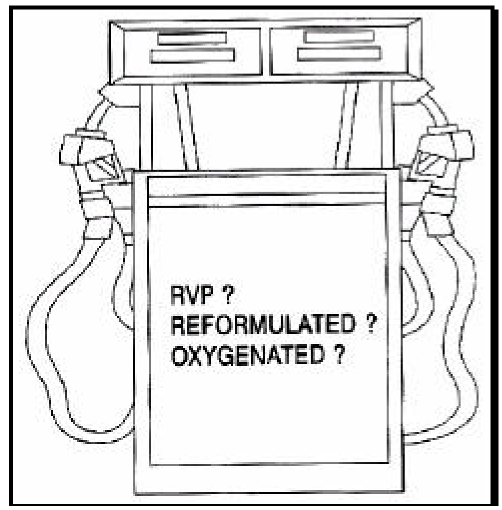
Trip duration	Default Value(% of VMI)
Under 10 minutes	6.744%
11 to 20 minutes	18.507%

21 to 30 minutes	16.775%
31 to 40 minutes	13.108%
41 to 50 minutes	8.335%
51 minutes and >	36.531%

The six percentages must sum to 1OO%. Note that the 6.744% value for under, 10 minutes represents the fraction of the total VMT that occurs in TRIPS that END WITHIN 10 minutes of their start, not the fraction of VMT that occurs within the first 10 minutes of longer trips. The values for other trip durations are defined similarly.

Fuel Characteristics

Emission Factor Model Components - Fuel Characteristics



RVP Corrections

The tests used to develop the BERs are conducted using a standardized test fuel known as Indolene so that the tests results are repeatable. However, Indolene is not the fuel drivers normally use in their vehicles. The differences in emissions resulting from the differences in fuel volatility, measured as Reid Vapor Pressure (RVP), between the test fuel and the fuel actually used by drivers is accounted for in the composite emission factors by using RVP correction factors to adjust the BERs.

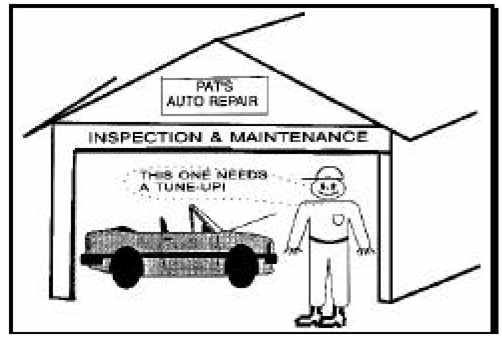
Fuel Formulation Variations

MOBILE5A has the capability to model the impacts on emission factors Of using both oxygenated fuels and reformulated gasoline. Both of these variations in fuel make-up can produce benefits (i.e. reductions) in CO and HC emissions. However, they typically have a very small effect on NOx emissions.

NOTE: These benefits as defined in the model are not dependent on travel related input data.

Emission Control Programs

Emission Factor Model Components - Emission Control Programs

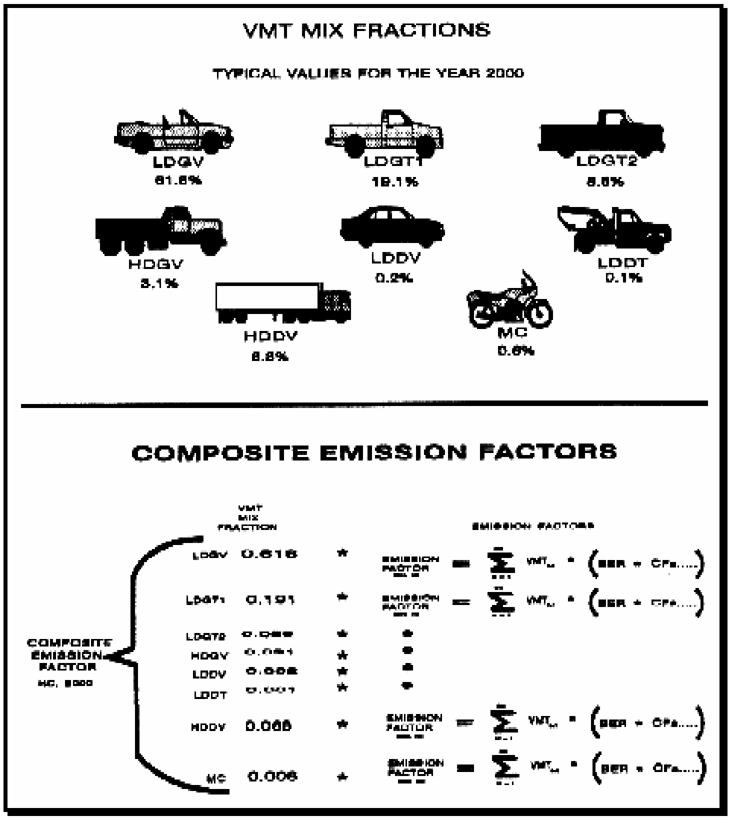


The BERs are purposefully developed to be reflective of emissions from vehicles not impacted by control programs. Thus additional adjustments to the BERs are necessary in areas where Inspection and Maintenance or anti-tampering programs are in effect. The procedures used within the model to estimates the emission reduction benefits from control programs are complex, especially for exhaust emissions. These calculations are based on vehicle technology parameters and the design and effectiveness of the vehicle emission control programs.

NOTE: The benefits as determined by the model are not dependent on. travel related parameters.

Emission Factor Model Components - Fleet Characteristics

Vehicle Miles Traveled (VMT) Mix Fractions

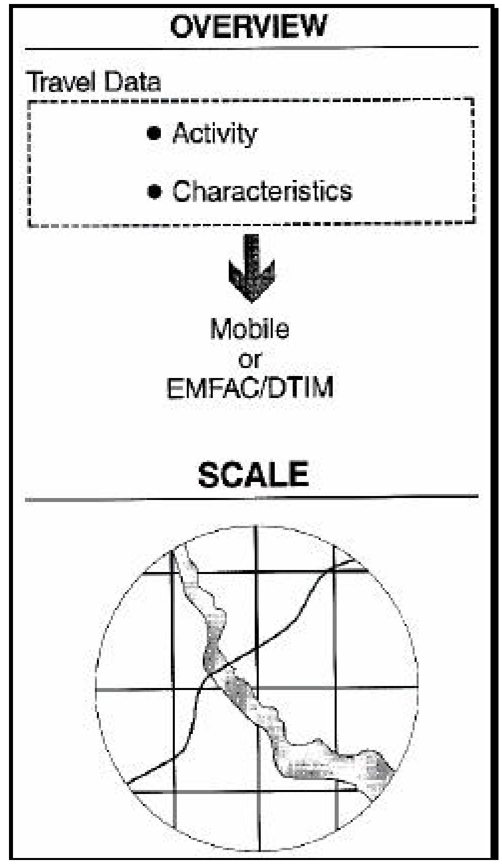


The MOBILE model produces emission factors for the following eight classes of vehicles: light duty gasoline vehicles (LDGV), light duty gasoline trucks 1 (LDGT1), light duty gasoline trucks 2 (LDGT2), heavy duty gasoline vehicles (HDGV), light duty diesel vehicles (LDDV), light duty diesel trucks (LDDT), heavy duty diesel vehicles (HDDV), and motorcycles (MC). The emission factor for each individual class is actually a composite emission factor though it is not called one. These eight class specific emission factors represent all the vehicle makes and models in their class. For example the emission factor for light duty gasoline vehicles represents all makes of gasoline fueled passenger cars including Chevrolet, Ford, Chrysler, Toyota, etc. of all ages that are assumed to be operating in the analysis year. "Composite emission factors" are defined in the MOBILE model as the sum of the eight vehicle class emission factors weighted by the respective VMT mix fraction.

MODULE 3: TRAVEL AND EMISSIONS MODEL INTERACTIONS

Introduction

The presentation will cover development of data related to travel that is required for input into emissions models. Needed data is of two types:



- Travel activity data that is output from travel forecasting models, which would be useful in developing emission model inputs.
- Other travel data which may not be directly output from travel forecasting models, but can be developed from travel model output data, perhaps in conjunction with travel survey data, for input to emissions models.

The type of input data needed for emissions models differs for the two emissions models currently used in the U.S.:

- EMFAC/DTIM (actually a sequence of three models — EMFAC, IRS, and DTIM) which is used in California
- MOBILE which is used in the rest of the country.

Geographic Scale

The type of input data needed also depends on geographic scale of the analysis:

- Regional analysis, which is generally done for ozone and CO analyses.
- Project level, which is generally done for CO analyses only.

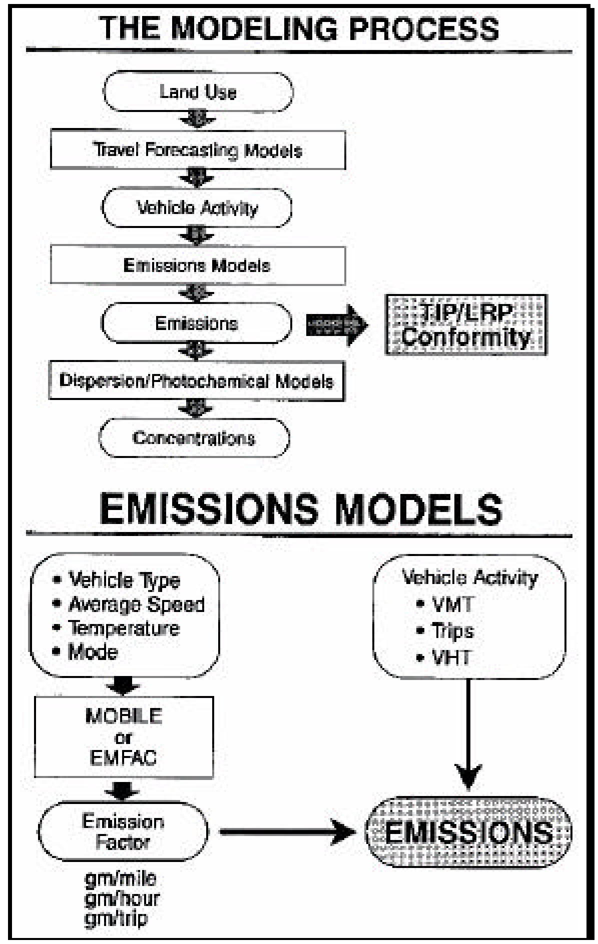
We will focus on data for regional analyses in this module. Project level analysis will be discussed later in this course (Module 6).

The Modeling Process

Types of Air Quality Analysis

The amount of detail needed for the travel input data to emissions models differs by the type of analysis to be done:

- Photochemical modeling: For air quality analyses involving use of a photochemical model, hourly emission estimates are needed for gridded areas, and for the episode day being modeled. Therefore, travel activity input data must not only be location specific, i.e. for specific links, but must also reflect the episode day i.e. season, month, and weekday or weekend being modeled.
- Other analyses: For other air quality analyses (e.g. conformity, SIP emissions inventories, TCM impact analyses, etc.), location- specific emissions and hour specific emissions are not needed; therefore, the requirements with respect to travel activity data are less detailed. For example, for conformity analysis, aggregate regionwide emissions -- one number -- is the final output to be calculated, and emissions may be calculated for an average day, rather than for a specific episode day. For emissions inventories on the other hand, more detail may be needed. For example, temporal breakdowns of emissions may need to be calculated, e.g. for peak vs. off-peak periods, owing to the sensitivity of emission rates to congestion levels. Also, season-specific data may be needed, i.e. summer for ozone analysis and winter for CO analysis.



Basic Structure and Inputs of Emissions Models

The structure of emissions models, both EMFAC and MOBILE, is the same:
Emissions = Emission factor x Vehicle Activity.

For MOBILE, travel activity is Vehicle Miles of Travel (VMT). For EMFAC, travel activity inputs are: (1) Vehicle Hours of Travel (VHT) (2) Number of trips (3) Park duration.

In both EMFAC and MOBILE, emission factors vary depending on several characteristics of travel activity:

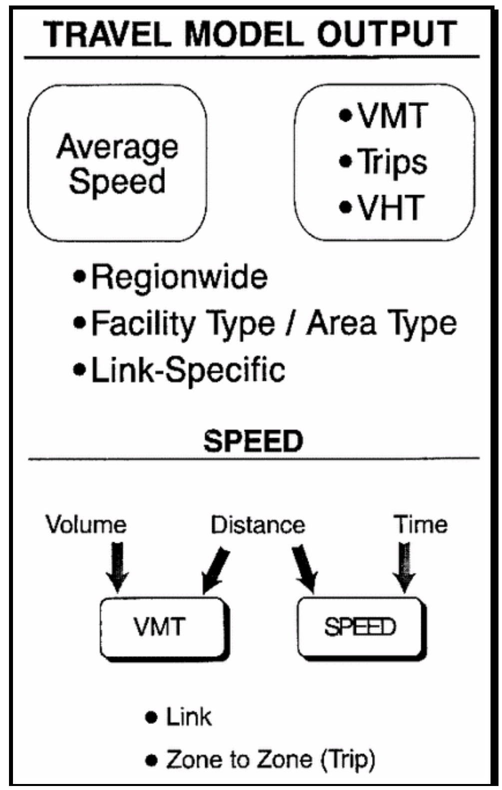
- Vehicle type and age mix
- Vehicle speed
- Time of day of travel, which determines ambient temperature
- Operating mode (i.e. hot/cold start mix, parking events (for EMFAC), and hot stabilized operation)

- Trip length distribution (which affects running loss emissions)

Travel Model Outputs

Of the above data requirements for emissions models, the following DAILY (or sometimes peak period and off-peak period) data are available from travel forecasting models:

- Link-specific traffic volumes (from which VMT can be calculated by multiplying volumes by the link length)
- Average speed on each link, obtained by dividing link travel time into distance.
- Zone-to-zone trips by trip purpose, and trip ends by Traffic Analysis Zone (TAZ) and trip purpose.



Also, using output from an assigned network, the following useful information can be "skimmed":

- "Congested" travel times between zones. (Note: If realistic speeds are not output from assignment, link speeds may first need to be adjusted, based on volume-to-capacity ratios for individual links.)
- Zone-to-zone travel distances on the shortest path between zones.
- Zone-to-zone average speeds, obtained by dividing time into distance.

VMT may be obtained either directly from the network, or by multiplying vehicle trip tables by distance skim tables.

Examples of network-based VMT calculations:

- Link VMT = link volume x link length.
- VMT for a specific functional class/area type = Sum of VMT on links in that class.
- Regionwide VMT = Sum of VMT on all links.

Examples of trip table based VMT:

- Zone-to-zone VMT = Zone to zone trips x distance
- VMT in a specific average speed category = Sum of zone-to-zone VMT for trips made at the specified average speed.
- Regionwide VMT = Sum of all zone-to-zone VMT.

Travel Model Output	**Problems**

VMT	Errors
	Missing VMT
	Daily (AAWT)
Travel Time/ Speeds	Not Calibrated
	Based on Unrefined Traffic
	Simple Relationships
Not Directly Available	Vehicle Type
	Operating Mode
	Temperature/Time of Day

Cautions

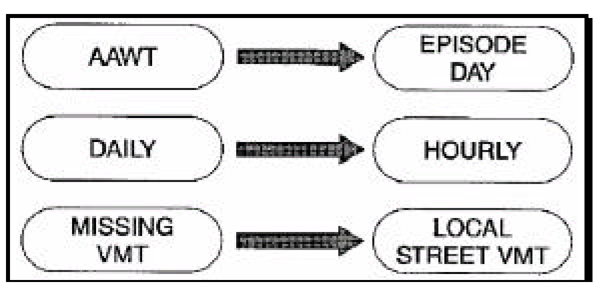
There are some cautions that need to be considered with respect to the use of these data:

- Volume Errors: Traffic volumes on specific links may be in error by as much as 15%-50%, depending on total traffic volume on the link.
- Local VMT: Aggregating link VMT over the entire system may reduce overall error to about 5% or less. However, it should be noted that all streets in the urban area are not reflected in the model network. Therefore, as much as 15% of regional VMT that occurs on local streets may not be accounted for in travel model output.
- Other "missing VMT": Generally, trips made by auto to park and ride lots are not assigned to the network. Some models fail to assign bus vehicle trips to the network.
- Link speed errors: Link speeds output directly from travel models are bound to be in error, for several reasons:

1. Travel times on which they are based are calculated using the unrefined traffic volumes (as much as 15-50% off) discussed in the first bullet.
2. Travel times are modeled using simplified volume/capacity to speed relationships rather than more rigorous traffic engineering based models.
3. Often, free flow speeds input into the model network are adjusted in order to reduce the error in traffic forecasts, and therefore may not reflect true free flow speeds. Unrealistic free flow speed input is bound to produce unrealistic congested speed output, even if traffic volumes and speed relationships are accurate.

Adjusting Traffic Volumes

Processing Traffic Volume Outputs



We will now show how some of the problems discussed above can be overcome in order to make travel model output more useful for input to emissions models.

As noted above, the above travel model outputs generally reflect DAILY travel activity, on an average weekday of the year. However, for photochemical modeling needs, HOURLY data is needed for the episode day.

Factoring for episode day: If the episode day is a weekday, link volume output can be factored to reflect the episode day using season/month/day of the week factors. If the episode day is a weekend day, conventional model output cannot be used, and the weekend day must be specifically modeled.

Factoring for time of day: Hourly factors reflecting the distribution of traffic by time of day can be used to estimate hourly traffic. These "diurnal" factors may be based on hourly traffic count data, or may be based on default factors by facility type, area type and facility orientation taken from National Cooperative Highway Research Program (NCHRP) Report No. 187. (NOTE: This report is currently being updated.) NCHRP Report No. 187 also provides factors by trip purpose and for total purpose. These could be used to get trip ends (needed for EMFAC/DTIM) by hour of the day. Alternatively, trip end percentages by hour of the day could be obtained from travel surveys in which time of travel information was collected.

Local VMT: "Missing" VMT on local streets which are not on the model network must be accounted for. This missing VMT can be derived from vehicle trip tables which provide the number of intrazonal trips by zone and an intrazonal trip distance based on:

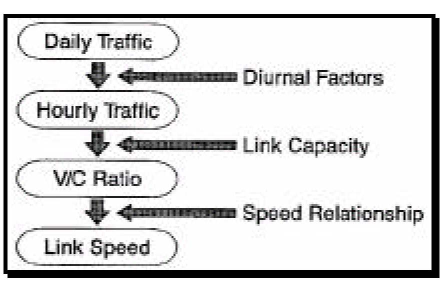
1. intrazonal trip lengths (in minutes) output from the trip distribution model.
2. assumed average (slow) speeds for intrazonal trips, since they are made on local streets.

These calculations are demonstrated in the Workshop which follows.

Park/Ride VMT: If trips to P/R lots are not assigned to links by the travel models, the "missing VMT" must be estimated on the basis of the number of such trips (based on output from the mode choice model), and average distance to P/R lots.

Adjusting Link Speeds

Processing To Get Link Speeds



Since speeds output from the transportation models do not reflect actual vehicle speeds on the links, speed values must be adjusted.

Detailed method: The most "accurate" method is the use of volume-to- capacity (V/C) relationships. The method involves the following steps:

1. Daily traffic is allocated to a typical peak hour and a typical off-peak hour of the day, based on traffic count data for various facility functional classes and area types.
2. V/C ratios are re-calculated for each typical hour.
3. Link-specific speeds are estimated using V/C relationships based on the Highway Capacity Manual.

However, V/C speed adjustment methods are resource intensive if they are to be done for each individual link, as would be needed if specific link emissions are to be estimated for photochemical modeling.

Less detailed method: An alternative, for use when VMT is estimated by aggregating network link VMT by facility class/area type would be as follows. Use average V/C ratios by facility class and area type to get average adjusted speeds by facility class and area type, for two representative time periods — peak and off-peak. Thus, an urban area with 5 facility classes and 4 area types would have to estimate only 40 adjusted speeds (5 classes x 4 area types x 2 time periods).

Vehicle Type Data

Regionwide	Vehicle Registrations (by County)
Link-Specific	Mix by Facility Type/Area Type
	Use Video Survey
Trip-Specific	Auto Log Survey

Developing Vehicle Type Data

Information on vehicle type and age cannot be directly obtained from travel model output. However, some vehicle type data is collected by State and local planning agencies during the traffic counting process. These data do not match the data needed for emissions models:

- Traffic count data does not distinguish between vehicles with different engine types (i.e. gasoline, diesel, electric).
- Vehicles with the same number of axles are grouped together e.g. light duty passenger cars and light duty trucks are often grouped under one classification because they both have two axles.

The options for developing vehicle type data vary depending on whether the analysis is link based or trip based.

Link based analysis: If link-based analysis is being done, special studies utilizing video technology must be performed to estimate link- specific vehicle mix. Using sampled links, a matrix of vehicle mix information can be developed on an hourly basis for typical facility type/area type link classifications.

If vehicle mix by functional class cannot be determined, State vehicle registration data may be used to estimate vehicle mix stratified on a county-wide basis. If no State data is available, national default data in MOBILE may be used.

If vehicle trip tables can be broken down by vehicle type (e.g. based on auto log survey data, as discussed below), the traffic assignment process could be used to estimate vehicle mix on individual links, and thus get VMT mix on individual links.

Trip based analysis: Some urban areas may have done auto log travel surveys, based on home interviews. A wealth of data on use of different vehicle types by trip purpose may be available from the survey. This information can be used along with trip tables by trip purpose and distance skims to estimate percentage VMT mix by vehicle type. The procedures will be demonstrated in the Workshop which follows.

Mode Data
(Link)

Model	Survey
Trips by Purpose and Hour	Percent Cold Starts

Traffic Assignment

VMT by Mode

Developing Vehicle Operating Mode Data: Link Based Methods

In MOBILE, operating mode fractions define the percent of VMT (not trips) assumed to be accumulated in the hot start, cold start and hot stabilized modes. These may be expected to vary:

- by time of day
- by facility type/area type

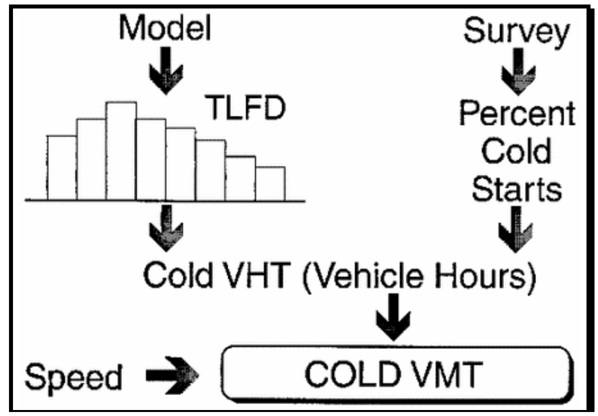
For example, in the morning most VMT will be in the cold start mode. Also, freeways and expressways will accumulate less VMT in the cold start mode than local roads.

Default MOBILE operating modes may be used for computing daily emissions estimates on a regionwide basis. Since photochemical models require location specific emissions, detailed operating mode distributions by time of day and by facility type/area type (or for individual links) may be necessary if the network link-based approach is to be used.

Detailed estimates of operating mode on individual links can be developed using enhanced versions of some proprietary travel demand software packages (specifically MINUTP and TRANPLAN) which allow trips in cold start mode to be traced on individual links in the assignment process. (See paper by William Allen and Gary Davies in Proceedings of the Fourth National Conference on Transportation Planning Methods Applications.)

Mode Date (Trip)

Developing Vehicle Operating Mode Data: Trip Based Methods



If a trip-based method is used for application of MOBILE emission factors, a single regionwide distribution of percent VMT by operating mode might be appropriate.

Detailed Method: One method of estimating this distribution using trip tables by purpose, distance skims, and travel time skims from the travel models, in conjunction with auto log survey data, is demonstrated in the Workshop which follows.

Less Detailed Method: An alternative method for developing VMT distribution by operating mode uses travel model outputs as follows:

- VMT produced by cold start trips by trip purpose, derived from vehicle trips by purpose in conjunction with percent cold start trips by purpose from auto log surveys, and distance skims.
- Distribution of trip lengths (travel time) by trip purpose.

Assuming that a vehicle operates in the start mode for the first 505 seconds, the proportion of total travel time that involves cold start mode operation can be determined for each trip purpose. These proportions can be applied to VMT by trip purpose to get cold start VMT by purpose. Aggregating cold start VMTs and dividing by all VMT will give percent VMT in cold start mode.

Quick Method: If trip length frequency distributions are not available, the percent VMT in the start mode can be estimated by dividing the average distance traveled in the start mode (first 505 seconds) by the average trip length, as shown-below:

Given: Urban area with 15 million VMT, 1.5 million trips and average highway speed of 25 mph.

Average distance in start mode: 505/3600 x 25 mi. = 3.5 mi.
Average trip length = 15/1.5 = 10 mi.
Therefore, % start mode VMT = 3.5/10 = 35%

To split start mode percent VMT into cold starts and hot starts, the share operating in cold start mode is estimated based on auto log survey data by trip purpose, and the start mode percent VMT is simply split into cold and hot starts based on this share.

California Emissions Modeling

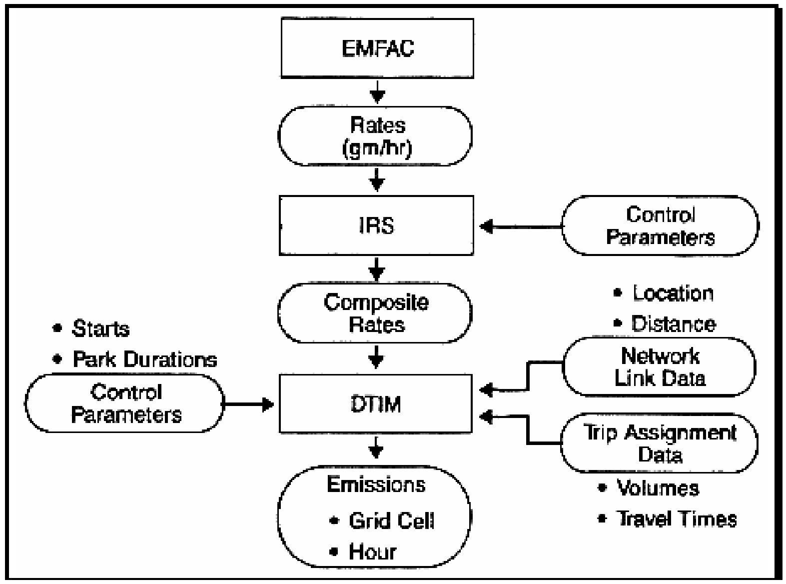
Transportation Data for EMFAC/DTIM

Running Exhaust (Link)
- Link Travel Time

Starting Exhaust (TAZ)
- Starts -- Hot & Cold

Evaporative (TAZ)
- Parks
- Park Duration

Transportation Data for EMFAC/DTIM



The California Air Resources Board (CARB) determined that basing emission estimates on only daily VMT and average operating speeds could produce highly inaccurate results. A new emission factor model was developed by CARB, which disaggregates emission rates into more explanatory component parts:

- cold start
- hot start
- running hot stabilized
- hot soak evaporative
- diurnal evaporative (i.e. emissions occurring whether or not vehicle is driven)

The California Department of Transportation (Caltrans) developed the Direct Travel Impact Model (DTIM) which couples emission impact rates produced by CARB's EMFAC and IRS models with transportation model data and ambient temperature data to compute emissions by square grid cell and hour of the day.

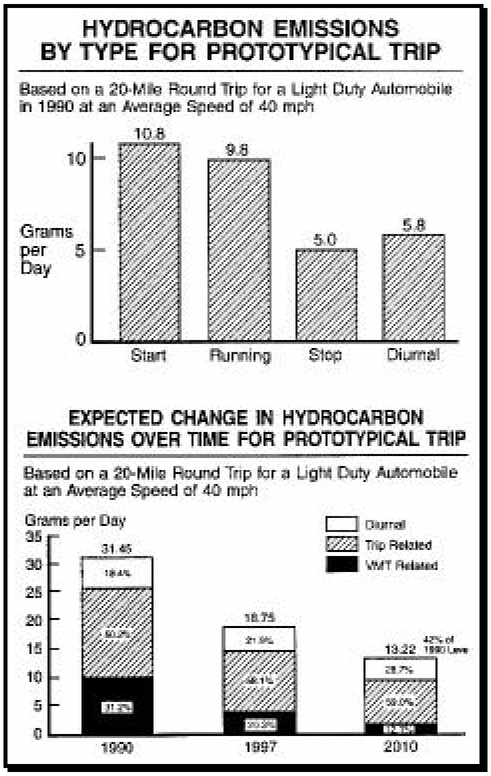
Transportation data needed for DTIM which is not needed for use with MOBILE are:

- number of trip ends (starts and parks)
- park duration

Emission Components Using DTIM

- Running exhaust emissions (link-specific): Emission factor x VHT (Note: VHT = link travel time x volume) (gm/hr)
- Starting exhaust emissions (TAZ specific): Emission factor x start mode VHT (gm/hr) (cold or hot)

- Evaporative (hot soak and diurnal) emissions (TAZ-specific): Emission factor x park duration



All of the emissions estimates and transportation input data are by time of day.

Emission Components: Sample Results

For a 20 mile round trip by a light duty automobile at 75 F and operating at a speed of 40 mph, in 1990, CARB's EMFAC model estimates show:

- 50% of emissions result from the trip being made, a combination of trip start emissions and evaporative hot soak emissions that occur at the trip end (i.e. starts and parks).
- About 32% of emissions are associated with VMT from the trip.
- The remaining 18% of emissions are diurnal emissions.

The importance of VMT as a determinant of emissions decreases over time. By 2010, only 12% of emissions will be VMT related.

Summary

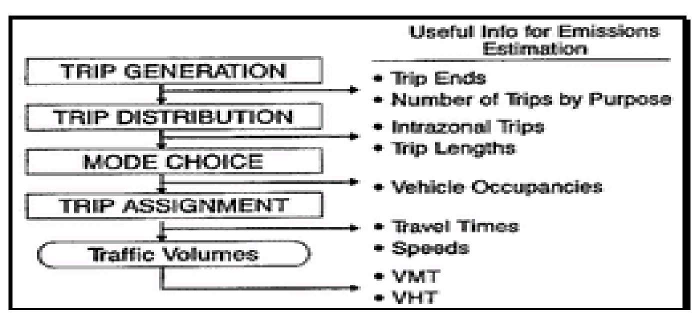
Transportation Data Needs Depend on:

- Emissions Modeling Process
  - MOBILE
  - EMFAC/DTIM
- Analysis Needs
  - Conformity
  - Concentrations

Travel Model Outputs

Conclusions/Summary

Travel models have many intermediate outputs which can be very useful in developing transportation inputs for emissions models.



Travel model data and further processing needed depends upon:

- Type of emissions models (EMFAC/DTIM or MOBILE)
- Level of detail of the air quality analysis to be done:
- Geographic scale of the analysis

We have discussed varying levels of detail which can be used to develop data needed for emissions models. Techniques have been discussed which use travel models or surveys, or from a combination of the two. Also, both link based and trip based techniques have been discussed.

We have emphasized transportation data needed for MOBILE and provided a brief overview of the differences in data needs for California's EMFAC/DTIM models.

Workshop: Developing Transportation Data for Emissions Models

The demonstration example uses ETOWN, a small hypothetical urban area with two traffic analysis zones (TAZs) and a highway network as shown in Figure 1.

Figure 1

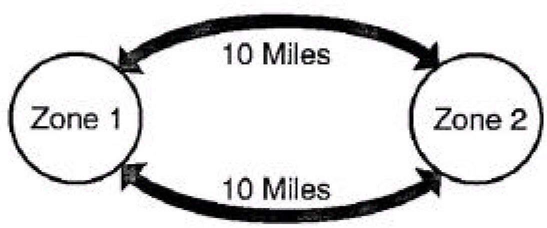


Figure 2

VEHICLE TRIPS

100	1500
1500	50

HB Work

600	2000
2000	300

HB Non-Work

300	1000
1000	150

NHB

Auto trip tables by trip purpose (HB Work, HB Non-work and NHB) have been developed for the peak period using ETOWN's mode choice model, and are presented in Figure 2. The auto trips were assigned to ETOWN's highway network using an equilibrium technique and the resulting volume/capacity ratios were used to compute adjusted travel times based on congestion; the results are shown in Figure 3.

A home interview (auto log) travel survey was also recently undertaken in ETOWN, from which it was determined that the percentages of auto trips starting in cold mode during peak periods were as follows:

HB Work -- 90%
HB Non-work -- 50%
NHB -- 30%

Based on the home interview survey, ETOWN planners were able to derive vehicle usage for peak period trips by trip purpose, as follows:

	Percent of Trips Using Vehicle Class		
	HB Work	**HB Nwk**	**NHB**
LDGV - Light duty gasoline vehicle	90	90	60
LDGT1 - Light duty gasoline truck 1	6	6	24
LDGT2 - Light duty gasoline truck 2	2	2	7
HDGV - Heavy duty gasoline vehicle	0	0	1
LDDV - Light duty diesel vehicle	0	0	1
LDDT - Light duty diesel truck	1	1	3
HDDV - Heavy duty diesel truck	0	0	3
MC - Motorcycle	1	1	1

For this demonstration, we will focus on peak period transportation data. We will develop the following transportation data for input to MOBILE, with appropriate levels of disaggregation:

- Peak period VMT
- Peak period speeds
- Distribution of peak period trip lengths
- Peak period VMT distribution by vehicle type
- Peak period VMT distribution by operating mode

The first step will involve estimating the VMT in each speed class which will form the basis for the MOBILE "scenarios" to be analyzed. Other transportation data required for input into MOBILE will then be developed for each scenario, specifically:

1. Distribution of trip lengths
2. VMT distribution by vehicle type
3. VMT distribution by operating mode

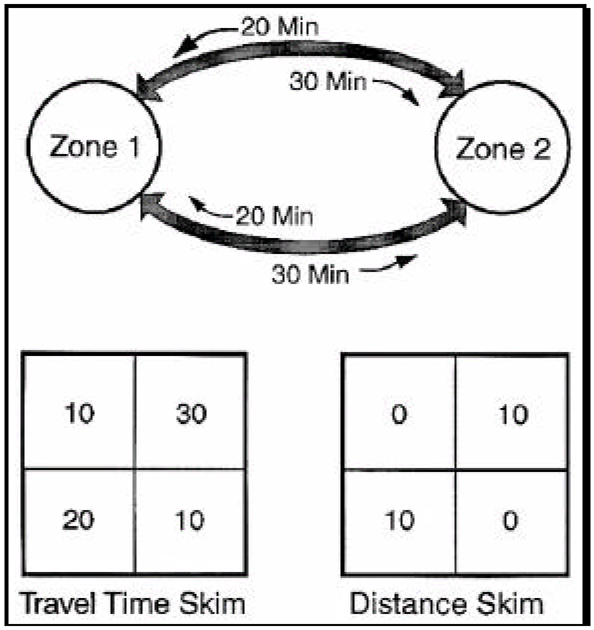


Figure 3: Assignment Results

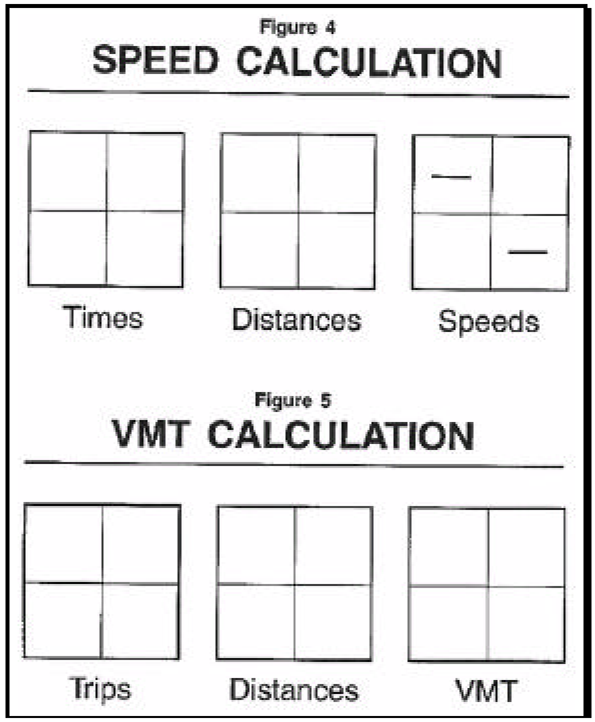
Step 1: Estimate VMT by Speed Class

This step involves the following substeps:

1. calculate average speeds between each pair of zones.
2. calculate VMT between each pair of zones.
3. classify VMT in each "cell" of the trip table into speed classes, and aggregate VMT by speed class.

1(a) Speed Calculation:

In Figure 4, we use the skimmed times and distances to calculate average speed for each zone pair. For example, speed between zone 1 and zone 2 = (10 min/30 min) x 60 min/hr = 20 mph. For intrazonal trips, we assume a low speed of 12 mph, since this travel will occur on local streets.



1(b) VMT Calculation:

In Figure 5, we use the auto trip table input into traffic assignment and the distance skims to calculate VMT for each zone pair. For example, total trips between zone 1 and zone 2 are 4500, and they travel a distance of 10 miles each. Therefore VMT = 4500 x 10 = 45,000 For intrazonal VMT, we first need to estimate an intrazonal average distance. This can be calculated using the intrazonal travel time and average speed of 12 mph assumed previously. For example, intrazonal distance for zone 1 = 12 mph x (10 min/60) = 2 miles.

1(c) Classify VMT

All VMT in a specified speed range is aggregated (see Figure 6). For example, intrazonal VMT, which travels at 12 mph, falls in the speed range 10-14 mph. Aggregating all VMT in the 10-14 mph speed range gives us (2000 + 1000) = 3000 VMT.

Figure 6: VMT Classification

Speed Range	VMT
0-4	_____
5-9	_____
10-14	_____
15-19	_____

20-24	_____
25-29	_____
30-34	_____

Step 2: Estimate Distribution of Trip Lengths

In this step, we simply classify VMT by trip length category to get the percentage distribution in each category (see Figure 7). For, example, all intrazonal VMT falls in the range 0-10 minutes.

Figure 7: Trip Length Distribution

Time Range (Minutes)	VMT
0-10	_____
11-20	_____
21-30	_____
31-40	_____
41-50	_____
51-60	_____

Step 3: Estimate Regional VMT Mix by Vehicle Type

For the purpose of this demonstration, we will simply estimate the percent LDGV. All other vehicle type percentages can be estimated similarly. First, we will estimate for each trip purpose the zone-to-zone trips and VMT by LDGV. Then, we will compute the percentage share of VMT by LDGV regionwide.

In Figure 8 (facing page), we first compute number of zone-to-zone trips by LDGV by purpose using the percent LDGV by purpose from the travel survey. Then, we calculate VMT by trip purpose by multiplying trip tables of LDGV trips (by purpose) by the distance skim matrix. A Total Purpose VMT table was calculated in Figure 5. We divide LDGV VMT by Total Purpose VMT to get LDGV

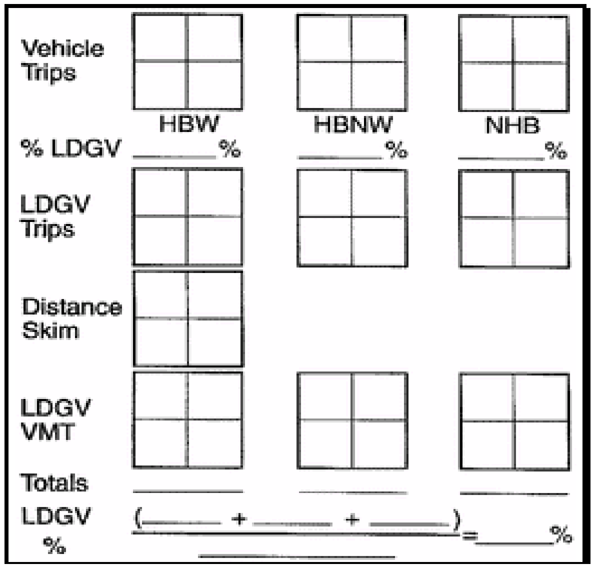


Figure 8: VMT Mix by Vehicle Type

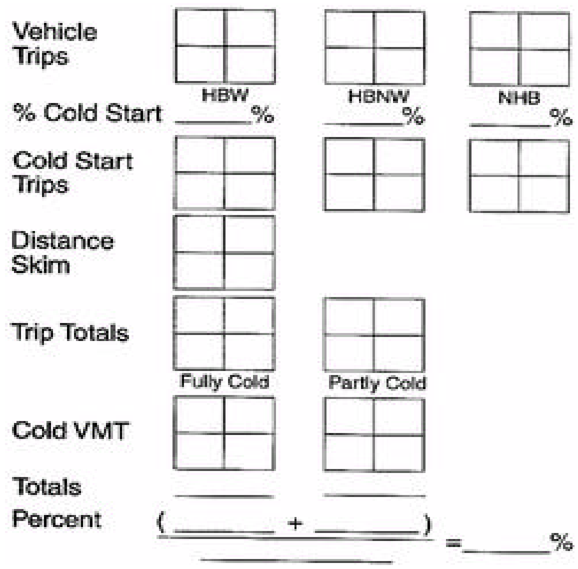
Step 4: Percent Cold Start VMT

Estimating percent cold start VMT involves the following steps as shown in Figure 9 (facing page):

1. Using each purpose's auto trip table and percent cold start trips by purpose, calculate cold start trip tables for each purpose. Aggregate all cold start trips into a Total Purpose cold start trip table.
2. Identify trip lengths shorter than 3.6 miles, and aggregate VMT for trips which are made entirely in cold start mode.
3. For trips longer than 3.6 miles, obtain cold start VMT by multiplying total cold start trips by 3.6 miles.
4. Percent cold start VMT is then obtained by aggregating VMT from substeps (b) and (c) and dividing by total VMT.

The above steps can similarly be used to estimate hot start VMT. The balance of VMT would be in the hot stabilized mode.

Figure 9: Percent Cold Starts



MODULE 4: VMT ESTIMATION

Overview

Terms and Methods

Applications
- Inventory
- Tracking
- Conformity

Terms
Geographic Boundaries
VMT Definitions
HPMS, Model
Other VMT

Overview

The purpose of this module is to provide information regarding the estimation of vehicle miles traveled for analysis relating to Conformity, VMT Forecasting and Tracking, and Emissions Inventory required by the Clean Air Act.

This session will discuss currently available techniques for developing reliable, credible estimates of vehicle miles traveled (referred to as VMT throughout this session) for regional mobile source emissions analysis. This includes: (1) The Terminology and Methodology related to Geographic Boundaries, HPMS vs. Model VMT, and other VMT such as off-model VMT, and VMT for the "donut area"; and (2) Applications: for developing VMT estimates for emission inventories, forecasting and tracking VMT in CO non-attainment areas, and conformity analysis. Techniques for obtaining consistency between Highway Performance Monitoring System (HPMS) and travel model estimates/forecasts will also be addressed.

Material in this Module is based primarily on Section 187, VMT Forecasting and Tracking Guidance, and Procedures for Emission Inventory Preparation, Volume IV: Mobile Sources.

VMT Terminology/Methodology

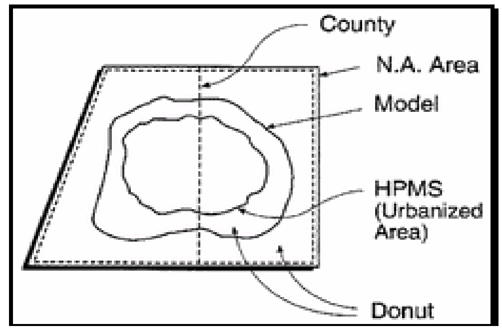
The first issue presented is the terminology and methodology applicable to all VMT forecasting. Topics covered are:

1. Geographic Boundaries
2. HPMS vs. Model
3. VMT Alphabet Soup

4. Other VMT
   - off-network
   - "donut"
   - local

Geographic Boundaries

This is an issue that arises with either forecasting method (and VMT tracking as well): geographic coverage.



Geographically, the modeled area may be considerably different from the HIPMS Adjusted Census Urban Area (ACUA); and neither may cover the entire non-attainment area. Or, the HPMS and model data may coincide, however the non-attainment area is larger than the area you have VMT estimates for. The area outside modeled or HIRMS boundaries is referred to as the "donut area".

VMT Alphabet Soup

ADT	VMT (ADT x Dist.)
A ADT	Annual
A AWDT	
A AWET	Daily
M ADT	
M AWDT	Hourly
M AWET	

VMT Alphabet Soup

VMT estimates prepared under Section 187, VMT Forecasting and Tracking Guidance are for annual VMT, while inventories will require VMT estimates for a shorter period or periods. For example emission inventories are based on episodic or seasonal counts, and conformity analyses are based on an Annual Average Daily Traffic.

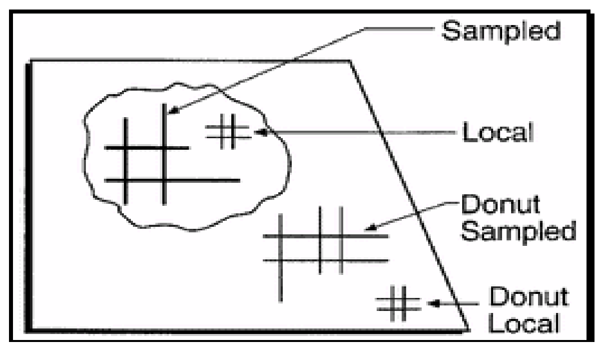
All adjustments to the functional system-specific annual VMT estimates, including, but not limited to, adjustments by month, day- of-week, and hour-of-day, should be fully consistent with the method used to adjust count-day ground counts to annual average daily counts for HPMS sample segments.

All VMT and all ADT are not created equal, as demonstrated in the listing of the alphabet soup relating to them:

1. ADT = Average Daily Traffic
    - Types of ADT:
    - AADT = Annual Average Daily Traffic,
    - AAWDT = Average Annual Weekday Traffic,
    - AAWET = Average Annual Weekend Traffic,
    - MADT = Monthly Average Daily Traffic,
    - MAWDT = Monthly Average Weekday Traffic.
2. VMT = Vehicle Miles Traveled = ADT * segment length
    - Types of VMT:
        - AVMT = Annual Vehicle Miles Traveled
        - DVMT = Daily Vehicle Miles Traveled. (average day, average weekday, weekend, etc.)

HPMS VMT

HPMS



Requirements of the Clean Air Act Amendments necessitate that states be able to produce annual estimates of VMT. EPA's guidance is based on the need to have a reliable VMT estimation methodology, applicable nationwide, that lends itself readily to annual use. HPMS was chosen for its ability to fill that role. Network-based travel demand models, with their time-consuming and resource-intensive updating procedures, are not a practical alternative to HPMS as an annual VMT estimation method.

The HPMS data collection and reporting procedures are based on both physical characteristics (number of lanes, capacity, etc), and usage characteristics (volumes, access, etc.). The data are required to be reported for "Universe" and "Sample" sections. Universe data consists of a complete inventory of length of facility by functional system, jurisdiction, and geographical location. The universe data are required to be reported on a section-by-section basis for rural arterials, urban principal arterials, and the entire National Highway System. The HPMS contains requirements for two types of samples; "standard" and "donut" area. "Standard" area is the entire area with the Adjusted Census Urbanized Area (ACUA). The "Donut" area is the area outside the ACUA but within the non-attainment area. Sample data are additional data that are added to certain universe data records for urban arterial and collector functional systems and rural arterial and major collector functional systems. For more information regarding HPMS there are manuals and training available through FHWA's Office of Highway Information Management, Highway Systems Performance Division.

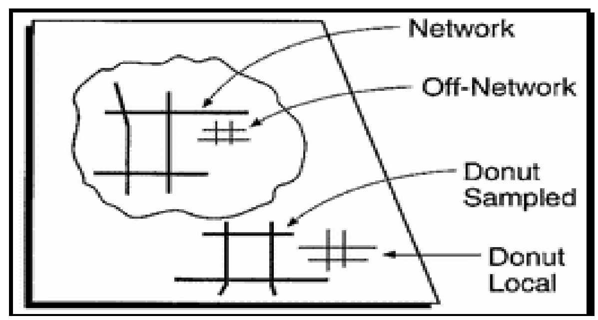
EPA and FHWA agreed upon the use of the Highway Performance Monitoring System (HPMS) as the foundation for VMT estimates. Accordingly, EPA's guidance for VMT projections recommends that

VMT reports be based on HPMS, and that HPMS serve as the base to which growth factors are applied.

HPMS does not sample VMT on local streets, and travel models do not normally include specific network links representing local roads and streets (and sometimes even collectors).
You may have HPMS data that cover the entire non-attainment area, but you will still need local VMT. For estimating local VMT in areas that do not have a method in place, use the HPMS local functional system VMT from area-wide VMT estimates by functional system.

Modeled VMT

While EPA prefers the use of HPMS for estimating areawide VMT, EPA encourages the use of travel demand models to temporally (i.e., by time of day) and spatially allocate VMT, and EPA allows the use of those models to estimate speed and other MOBILE model variables. The models provide information that is not necessarily available with HPMS.



EPA also requires the use of models for estimating the emissions impacts of transportation plans and programs, and after 1995, for conformity determinations in nonattainment areas classified as serious and above.

As mentioned above, model VMT must be reconciled with HPMS VMT prior to use. Methodology for reconciling model and HPMS VMT is the topic of the next discussion.

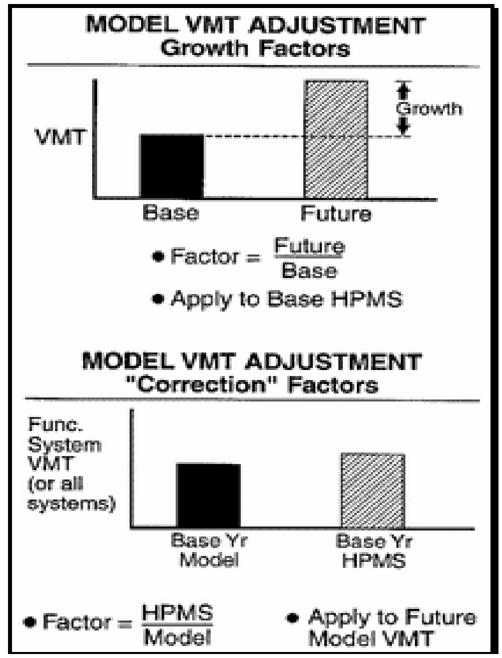
Model VMT, like HPMS VMT, does not account for certain types of VMT such as "off-network" VMT and the VMT of the "donut area". Methodologies for estimating "off-network" VMT and "donut area" VMT are discussed elsewhere during this session.

Under specific circumstances (delineated in EPA guidance) the use of network-based travel demand models to estimate 1990 VMT is permitted. This exception to the use of HPMS only applies in situations in which the 1990 ground counts submitted to HPMS are particularly "weak" and the network model is "strong". States should use this method only with permission.

Remember that the VMT counts for the model are 5 day, week day counts and the HPMS are 7 day, week long counts. As stated earlier; VMT estimates prepared under Section 187, VMT Forecasting and Tracking Guidance are for annual VMT, while inventories will require VMT estimates for a shorter period or periods. All adjustments to the functional system-specific annual VMT estimates, including, but not limited to, adjustments be month, day-of-week, and hour-of-day, should be fully consistent with the method used to adjust count-day ground counts to annual average daily counts for HPMS sample segments.

Model VMT -- Adjustment

Models can be used to forecast VMT, but the VMT must be adjusted based on HPMS.



According to Section 187, VMT Forecasting and Tracking Guidance, the network-based model used to estimate VMT in 1990 at a minimum should be validated with 1987 or more recent ground counts and should use demographic inputs properly updated to 1990. An area using this method should make sure that all VMT in the non-attainment area is included in the estimate.

Method 1 -- Growth Factors

If an area's network-based travel demand model is properly updated and validated according to the specifications described in Section 187 guidance, the model may be used to develop growth factors which would then be applied to base year HPMS VMT. In essence, an area using this method would apply the ratio of future VMT to base year VMT, as determined by the model, to the official base year VMT obtained from HPMS. This method is demonstrated on the facing page.

$$\text{Forecasted VMT (future)} = \text{Actual VMT (1990)} * \frac{\text{Travel demand model VMT future}}{\text{Travel demand model VMT (1990)}}$$

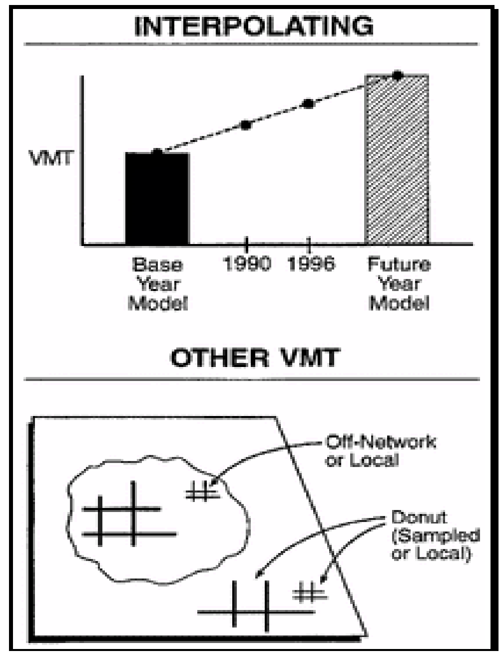
Method 2 -- Adjustment Factors

In the base year, the modeled VMT and HPMS VMT are known. But since the modeled area and the HPMS (ACUA)/ area often differ, the first step in making model VMT consistent with HPMS VMT is to make non- attainment area VMT consistent with HPMS VMT. Essentially this adjusts modeled VMT to reflect the difference between HPMS and modeled VMT in the base year. This method is demonstrated on the facing page.

Network links in the model are identified with HPMS functional systems. An Adjustment factor, derived from the ratio of non- attainment area HPMS VMT to model VMT, is applied to model VMT by functional system. Note that, since HPMS and model boundaries may be incompatible, only links on which are included on both systems must be used in developing the ratio. If a state demonstrates that making an adjustment by functional class is not feasible due to inconsistent roadway classification schemes, data problems, or constraints on time and staff, the state may make one overall adjustment.

Interpolating

If model output is not available for some of the required VMT forecasting years, the state or MPO should linearly interpolate between chronologically adjacent travel demand model scenario years to calculate values of modeled VMT.



Other VMT

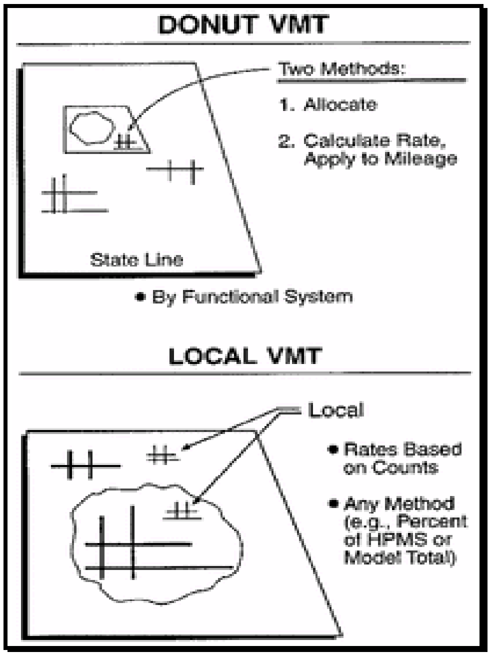
Other VMT data are required, but not available from the HPMS, nor the model.

There three possible "Other VMT" data types needed: (1) "Off-Network" VMT, discussed in the travel demand or the emission factor module, (2) "Donut Area" VMT and; (3) Local VMT.

"Donut" VMT

As was previously discussed, the model and HPMS data must be reconciled ("adjusted"), so as to be able to expand the data coverage area to include the entire non-attainment, or "donut area".

For the "donut area" VMT, the most efficient approach may be to develop rates of VMT/mile by functional system. from the state-wide rural or small urban samples and apply them to the rural and small urban mileage in the "donut area".



HPMS universe data includes Interstates, Other Freeways, and Other Principals. The sample data includes rural minor collectors, Rural Local and Urban Local functional systems

It should be noted that local VMT would still be required.

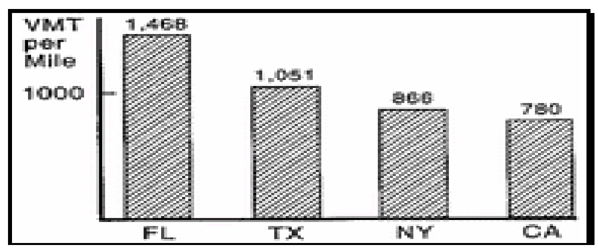
Local VMT

For CO non-attainment areas subject to Section 187 provisions, local VMT estimates should be count based for 1995 and later years. Prior to that, states may use local road VMT estimates reported to HPMS or another reasonable method.

Local VMT includes VMT on rural Minor Collectors, rural local and urban local streets.

Local VMT Count-Based Rates

WHY VMT?
- Inventory: Base, Future
- Tracking/Forecasting
- Conformity: Regionwide



Local VMT/Mile Rates

Rates of local VMT vary depending on such factors as availability of roads, type of terrain, barriers to development, population density, type of street network, etc.

Examples of local VMT/mile rates from states are displayed on the facing page. This data comes from Illinois, Chicago area, Mobile Source Emission Analysis Report. FHWA is currently sponsoring research through the Transportation Systems Center to develop approaches to estimate local VMT from traffic counts.

II. Applications

The previous section discussed basic terminology and methodology. In this section, we will discuss how the methodologies are applied in various applications.

1. developing emissions inventories;
2. VMT forecasting and tracking; and
3. conformity determination.

EMISSIONS INVENTORY
- 1990 Base
- Periodic
- Baseline for Determining Future Reductions

1990 INVENTORY

HPMS	**Model**
VMT	-- Allocate VMT
	- Time
	- Location
	- Mode
	- Speed

Emissions Inventory

The VMT used to construct mobile source emission inventories should be consistent with that reported through HPMS. EPA requires consistency between SIP (VMT used for emission inventory) and HPMS VMT. Besides the differences resulting from developing VMT by other methods, the most common variations occur when the non-attainment area is geographically different from the Adjusted Census Urbanized Area (ACUA), or when VMT on local streets are not available.

Emission inventories were developed by states for the 1990 base year, for use in developing SIPs due in 1992, for CO, and 1993 & 1994, for O_3. These inventories will have to be updated for future SIP revisions.

1990 Base Year Inventory

1990 VMT should be based on HPMS because it is the only standard uniform annual, quality assured sampling/collection/tabulation of traffic count data across the nation.

Models can be used to spatially and temporally allocate areawide VMT. For example, network models may be used to distribute VMT by:

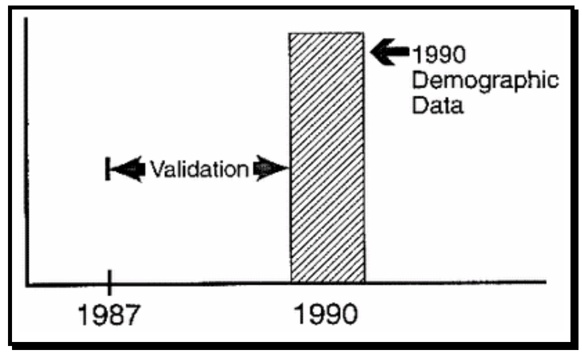
- Time of day or Peak/off peak
- Geographical Location
- Operational Mode or Trip starts, etc.
- Speed

1990 INVENTORY

Model Could Be Used under Certain Conditions

1990 Inventory Use of Model

1990 Base -- Exception



There is an exception to the use of HPMS VMT for 1990. For 1990 only, Model-based VMT is acceptable under certain conditions:

- Urban areas are in a state which is "grouped" by urbanized area for sampling purposes in 1990.
- HPMS traffic counts are poor.
- Substantial emissions inventory progress has been made.
- Models have been validated since 1987 and 1990 demographic and economic inputs were used in model.

States adopting this approach should realize that, beginning in 1993, all urbanized areas with a population above 200,000 will be required to conduct HPMS sample panels for individual ACUAs and, therefore, will be required to estimate mobile source emissions in such a way that the VMT estimates used by the state are consistent with HPMS. This means that there should be no reason for an ozone area with poor HPMS data in 1990 not to base the "periodic inventory" for 1993 and the Reasonable Further Progress tracking inventory for 1996 on HPMS estimates, even if EPA accepted another method for the 1990 inventory. This switch in basis for the inventory may reveal that the method used for 1990 was not accurate, and it may be disadvantageous in terms of demonstrating progress in emissions reduction. A possible solution is for the area to project 1990 VMT backwards from the higher quality 1993 HPMS figures and submit a revision of its 1990 inventory using this revised estimate of 1990 VMT. Where the disparity between 1990 and 1993 estimates by two different methods appears to EPA to constitute an erroneous estimate of actual VMT changes, EPA may require such backward projections from 1993 data.

1990 Base -- Model

Models used must have been validated since 1987, and 1990 demographic and economic inputs must be used in the model. And under conditions other than those noted above, model VMT should be adjusted to be consistent with HPMS VMT.

FORECASTING/TRACKING

- CO Above 12.7 ppm

- Ozone: Serious, and Above

VMT FORECASTS

- Using Model:
  1. Growth Factors
  2. Adjustment Factors
- Discussed on P. 4-12

VMT Forecasting and Tracking for CO non-attainment areas with 12.7 ppm and above, and Ozone non-attainment areas

Guidance of Section 187(a) of the Clean Air Act Amendments of 1990 (CAAA) offers the EPA's recommendations on how to forecast and track VMT in Moderate and Serious carbon monoxide (CO) non-attainment areas with design values greater than 12.7 ppm at the time of classification.

The purpose of the guidance is to help states prepare State Implementation Plan (SIP) revisions that EPA can readily propose to approve as meeting the requirements of the CAAA.

All states containing a moderate and/or Serious CO non-attainment area with a design value greater than 12.7 ppm at the time of classification should estimate annual VMT using HPMS. The VMT should be derived from estimates of VMT on all functional systems within the corresponding ACUA.
The Section 187 Guidance recommends two methods for determining future VMT growth: (1) Developing growth factors from a network-based travel demand model; or (2) Using a linear extrapolation of recent (6-year) HPMS VMT reports to the Federal Highway Administration.

VMT Forecasts -- Model

CO non-attainment areas are required to annually prepare forecasts of VMT, using technical procedures outlined in Section 187, VMT Forecasting and Tracking Guidance, which involve use of models (or past trends) to factor base-year HPMS VMT estimates.

For Serious CO areas, model-based growth factors are applied to HPMS. Models must be validated for 1985 or later. All states containing a Serious CO non-attainment area should forecast VMT by applying growth factors, based on a validated network-based travel demand modeling process, to the 1990 annual HPMS VMT estimate.

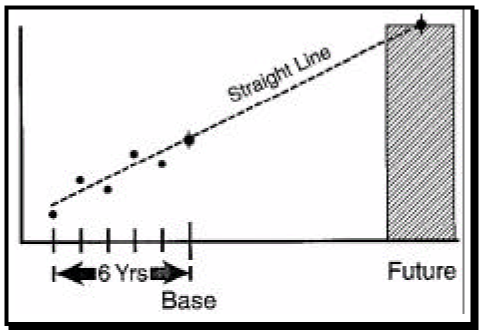
The growth factor is derived by dividing the modeled future VMT by the modeled 1990 VMT. this factor is then multiplied by the 1990 HPMS VMT.

$$\text{Forecasted VMT (future)} = \text{Actual VMT (1990)} * \frac{\text{Travel demand model VMT (future)}}{\text{Travel demand model VMT (1990)}}$$

VMT Forecasts: Trend-Based

VMT Forecasts -- Trend (HPMS)

All states containing a moderate CO non-attainment area with a design value greater than 12.7 ppm at the time of classification should forecast VMT in the nonattainment area using the historical HPMS trend method if no model is available.



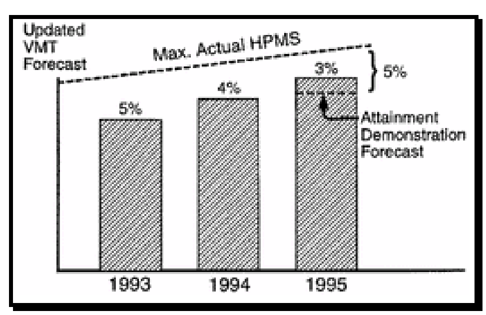
If the lead planning agency of the non-attainment area, in consultation with appropriate other state and local organizations, determines that a validated travel demand model is not currently available, then a state may request approval to use historical area- wide VMT based on HPMS data. VMT forecasts must be based on growth factors derived from an ordinary least squares linear regression extrapolation of the state's HPMS reports. Please note that the linear projection results in a declining percentage growth rate over time, because a compounded growth rate always produces an upward (concave) curve. However, EPA believes that linear growth is the better model for VMT.

The Section 187 Guidance specifies the 1985-1990 time frame as the period over which to estimate the linear trend. It also specifies that projections done in later years be based on the most recent six year period for which data have been submitted and finalized by the HPMS. If HPMS final data are available for years beyond 1990, these data may be used to calculate the initial six-year trend. For example, if HPMS data are available, the trend may be calculated from the 1986-1991 period.

For areas that do not have a current set of calibrated models, the VMT/mile rate method using HPMS data may be used for the entire area outside the urbanized area (i.e., the "donut area").

VMT Tracking

VMT Tracking involves comparing actual annual HPMS VMT with forecast VMT. Under the Section 187 requirements, moderate and serious CO non- attainment areas with a design value greater than 12.7 ppm must forecast VMT for each year prior to the attainment year, estimate actual VMT in each year for which a forecast is required, and annually update the VMT forecasts. It is a "truth in forecast check" done annually. It is intended to spot situations in which the actual VMT growth occurring in the nonattainment area is higher than the forecasted VMT growth used in the attainment demonstration.



Non-attainment areas must annually compare forecasted VMT with the HPMS VMT for the current year. Areas are required to use HPMS in estimating current-year, VMT. The comparison between HPMS and forecasted VMT is called tracking.

Contingency measures (TCMs from the SIP) are automatically enacted if the HPMS VMT or a subsequent forecast is higher than the most recent prior forecast by more than a certain percentage. EPA believes it is appropriate to allow a margin of error of 5.0% for VMT comparisons made in 1994 based on HPMS data collected for 1993, a margin of 4.0% for VMT comparisons made in 1995 based on HPMS data collected for 1994, and a margin of 3.0% for VMT comparisons made in 1996 and thereafter based on HPMS data collected for 1995 and later years. However, EPA believes that the adjustment of forecasts are appropriate only as long as, cumulatively, estimates of actual VMT or revised VMT forecasts never exceed by more than 5.0% the VMT forecast relied upon in the area's attainment demonstration. Please note that safety margins can be incorporated into forecasts.

VMT Tracking (contd.)

The designated CO non-attainment area may not be the same size as the ACUA and as previously discussed, there is a need to resolve VMT within the boundary of the nonattainment area.

Because HPMS provides information by facility type, and data is disaggregated to general categories such as urban and rural area types, it is difficult to allocate VMT to specific locations (i.e., TAZ or grid) within the boundaries of the FHWA defined ACUA. And since the ACUA, in turn may not fully encompass the non-attainment area and generally does not follow political boundaries, states should identify a VMT Tracking Area for the purpose of VMT forecasting and tracking.
The boundaries of the VMT Tracking Area should be consistent with those of the of the several CO inventories required of CO non- attainment areas to the extent that VMT in the areas can be logically related. In addition, the boundaries generally should not be smaller than the ACUA that contains or overlays the designated non-attainment area since HPMS produces a statistically valid sample on for the ACUA as a whole. However, a Tracking Area smaller than the ACUA may be appropriate if it encompasses all vehicle travel contributing to the non-attainment situation and if the state or another designated entity operates a VMT tracking system equivalent in performance to HPMS for that area. The VMT Tracking Area need not exceed the limits of the ACUA.

All states subject to the VMT forecasting/tracking provisions should base their 1993 and later calendar year's estimates on HPMS annual VMT from the sample design for each urbanized area. All counts used in the VMT estimates should also be submitted as HPMS counts, so they meet the HPMS quality assurance guidance and are subject to FHWA review.

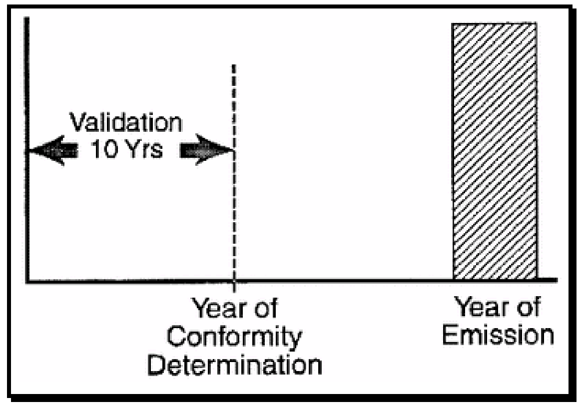
VMT Tracking - Ozone Nonattainment Areas

Tracking in serious and above Ozone non-attainment areas is done using the same methods as in CO non-attainment, except the contingency provisions and the reporting criteria do not apply. When forecasting VMT in Ozone non-attainment areas through 1996, the use of HPMS trend data is allowed.

However, after 1996, model-based data are required for attainment and Reasonable Further Progress (RFP) demonstrations. Beginning in 1996 and each third year thereafter, the state shall submit a demonstration as to whether current aggregate vehicle mileage, aggregate vehicle emissions, congestion levels and other relevant parameters are consistent with those used for the area's attainment demonstration. See Section 182(c)(5) of the CAAA.

Conformity Using Model

CONFORMITY
- Regionwide Emissions
  - Budgeted
  - Build
  - No-Build



Conformity

It is required that all non-attainment areas certify that transportation plan, programs, and projects are in conformity with plans for improving air quality in the area.

Serious & Above CO and Ozone Non-Attainment Areas (Requirements after 1/1/95)

After January 1, 1995, the rule requires that serious, severe, and extreme ozone and serious CO areas must use state-of-the art travel demand models for analysis. Model based analysis must be performed for emissions within the non-attainment area.

Technical analysis required to support conformity determination involves model-based analysis for emissions, for build and no-build scenarios. In the future, emissions will have to be compared to emissions budgets developed for the mobile source portion of the SIP. The model must be validated against ground counts for a base year that is not more than 10 years prior to the date of the conformity determination, not the plan year, nor TIP year.

Since neither the travel demand model domain, nor the Adjusted Census Urbanized Area (ACUA), which is the geographic base for HPMS, may coincide with the non-attainment area, states may use "any reasonable methodology" to project VMT within the nonattainment area but outside of either method's purview.

Serious & Above CO and Ozone (Method)

A factor is developed by dividing model-based VMT into HPMS VMT in the base year. The factor is applied to model-based forecast to get the future estimate of VMT (forecasted HPMS).

"Reasonable methods" are to be used for off-network and outside planning area. (These were discussed previously)

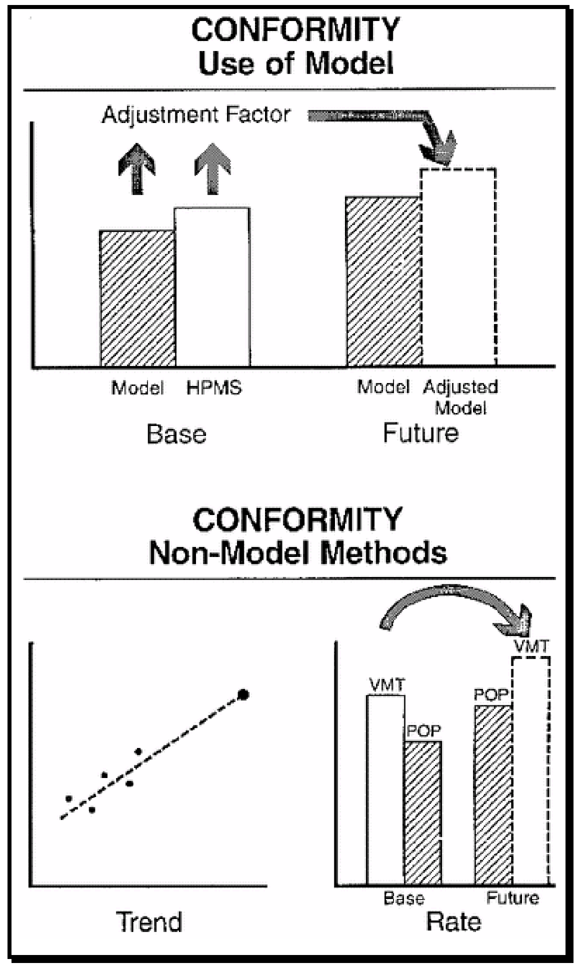
Conformity Determinations For All Other Non-Attainment Areas (moderate, etc.).

If other non-attainment areas (moderate, etc.) do not have models, they may quantify emissions using "less refined" methods. For example:

Trends, or VMT rates per person.

The difficult part would be estimating differences with and without proposed projects, programs or plans. Apparently, the only difference is in future speeds, especially if "induced" travel is ignored as a non-issue. Since average speeds can be expected to improve with the projects, reduced CO and HC emissions could normally be expected. Also note that NOx emissions may increase with increases in average speeds.

There are a myriad of different options for determining the proper method of VMT estimation. Each area will need to develop the method they, in conjunction with EPA deem appropriate for their situation.



SUMMARY

HPMS Model

-- Inventories
  - 1990, Periodic
  - SIP Baseline
-- Conformity
-- Tracking/Forecasting

Summary

During this session we discussed VMT estimation techniques. First we determined the terminologies and methodologies that are applicable to VMT estimation. We discussed the differences between HPMS and Model VMT, and how to obtain consistency between them, as well as processes for determining the off-model, local, and "donut area" VMT.

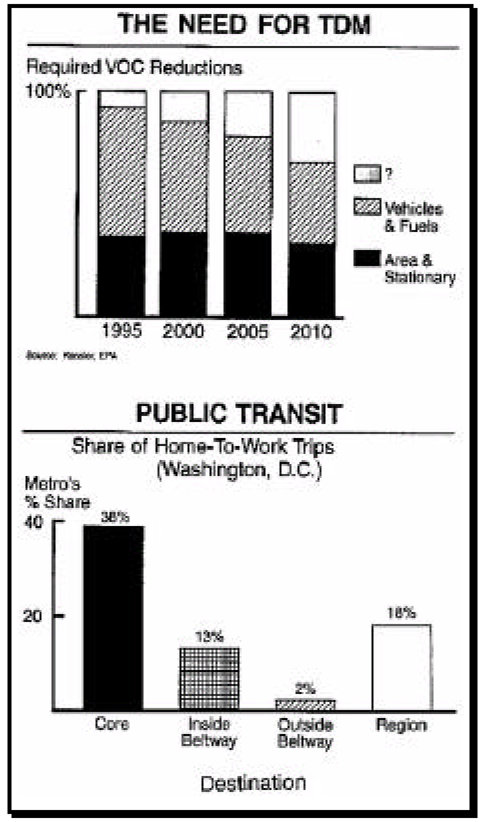
The applications of VMT estimation were also a focus of the lesson. VMT estimates are done for emission inventories, forecasting and tracking VMT in CO non-attainment areas (12.7 ppm and higher), and conformity analysis.

MODULE 5: ASSESSING TCM EFFECTIVENESS AND IMPACTS ON EMISSIONS

The Need for TDM

To achieve CAAA targets, states will have to go beyond required actions and implement additional TCMs:

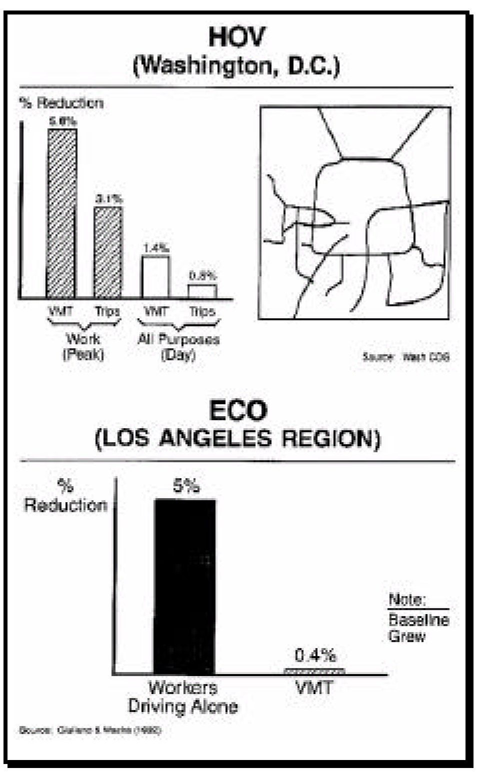
- Incentives for even cleaner technologies.
- Traditional and innovative travel options.
- Effective transportation demand management.



Public Transit

- Small share of the market
- Effectiveness varies with density
- Not cost-effective, on its own

Note: The Washington "Core", for which data is provided on the facing page, is broadly defined to include all centrally located employment areas, including those in Virginia (i.e. Crystal City, Pentagon, and Rosslyn). Source of the data: Jim Hogan, "What Can Transit Really Do?" The Region, Vol. 31, No. 3, Winter 1991, pp. 18-21, WMCOG.



HOV

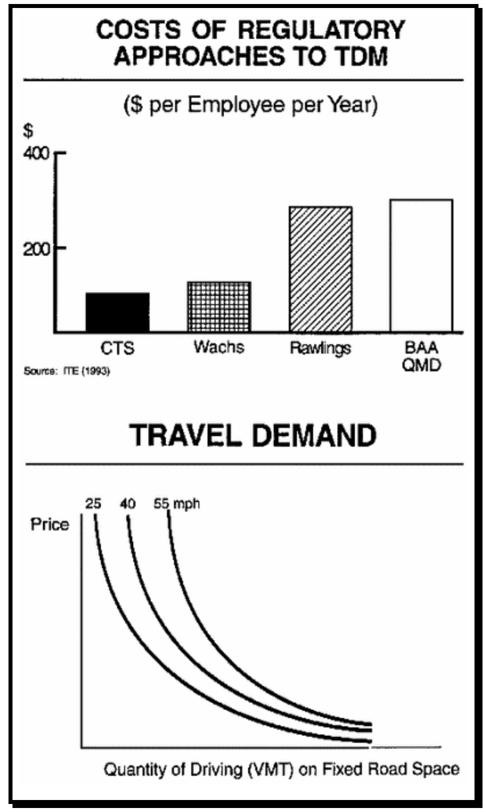
- Has limited attraction
- Emissions benefits reduced by Park-and-ride trips and slow speeds for picking up passengers

TDM By Regulation

- South Coast (Los Angeles) Reg XV - largest experiment yet in TDM
  - Applies to employers of 100 or more at any site
  - Must file and execute a plan to increase average vehicle ridership to specified targets
  - Must have a trained employee transportation coordinator
- Regulation 15 in South Coast area:
  - Drive alone trips dropped from 76% to 65% at firms
  - VMT dropped by 0.4% regionally, not enough to mitigate growth

Costs of Regulation

Financial costs for Regulation 15 are substantial.

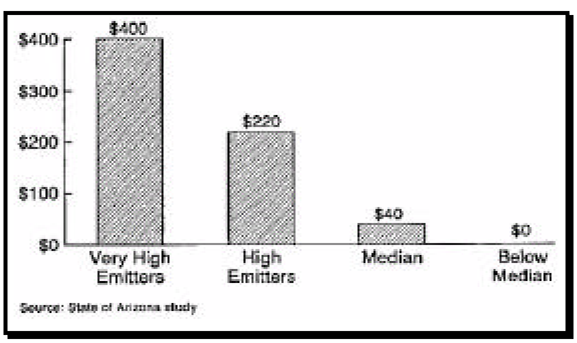


TDM Through Pricing

- Prices have strong influence on behavior
- Advantages over regulatory approach
  - Applies to all types of drivers and all kinds of trips
  - Preserves individual choice
  - Practical to implement and enforce
  - Encourages creative minds to develop travel alternatives
  - Can't be avoided by maneuvering - such as moving work site just across nonattainment area boundary
  - Gives big boost to transit
  - Can encourage use of cleaner vehicles and fuels
- However, net benefits of pricing strategies depend on the wise use of the revenues they generate.

STRATEGIES THAT WORK

-- Feebates	-- Congestion Pricing
-- Scrappage	-- Parking Pricing
-- VMT/Emissions Charges	-- Telecommuting
	-- Paratransit



Feebates

An age-normalized fee schedule that varies with emissions: Vehicles 1983 or later

Mobility - Air Quality Strategies That Work

- Strengthen tailpipe and fuel standards with market incentives for a cleaner fleet
- Improve efficiency by cutting taxes and leaving the costs of roads to drivers
- Reshape harmful parking subsidies into more valuable employee benefits
- Unlock the potential of innovative travel alternatives by eliminating barriers to private transit and telecommuting

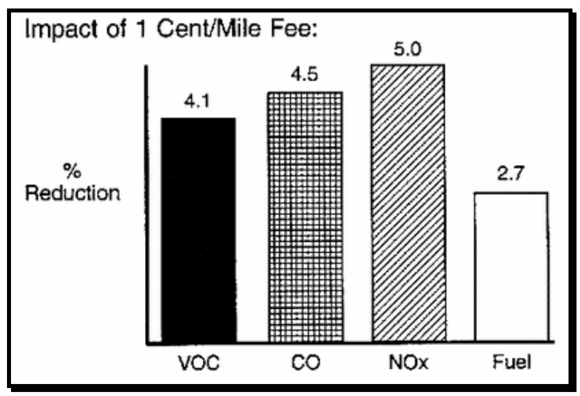
Feebates

- Limitations of emissions and fuel economy standards
  - Manufacturers have no reason to go beyond the standard
  - Consumers have little opportunity to select cleaner vehicles
  - Trends are towards large cars and trucks, dirtier classes of an admittedly cleaner fleet
- Feebates are financial incentives and disincentives applied to the purchase price of vehicles
  - Can be revenue neutral
  - Easily enforced
  - Can be state or federal action
- Feebate schemes introduced in 14 states and in the US Congress

SCRAPPAGE
- Hastens Fleet Turnover
- Interim Strategy

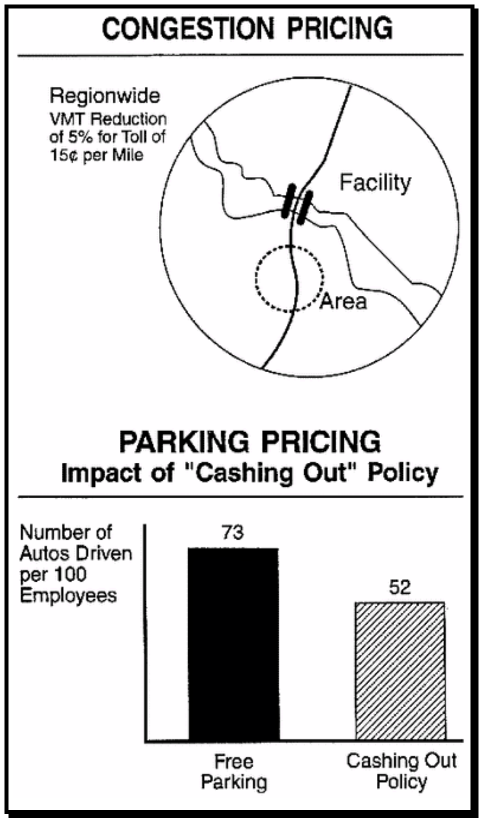
VMT Taxes and Smog Fees

Scrappage
- Slow fleet turnover undermines impact of technological, progress and standards
- But effectiveness of scrappage depends on
  - Ability to identify heavy-emitters
  - Fair weather conditions that foster slow fleet turnover
  - Scrapped vehicles not being replaced with other old cars
- Scrappage is, at best, an interim strategy. It can speed up reductions that would have occurred anyway as fleet turned over in due course.



VMT/Emissions Charges

- A tax paid annually on the basis of odometer readings at annual registration or smog check
- Could supplant other revenue sources such as income, property, sales, or other taxes
- Could be indexed on the basis of emissions
- Advantages over a gas tax
  - More directly targets penalties at the undesirable activity
  - More difficult to escape in many jurisdictions
  - By replacing taxes on income, sales, etc, a VMT tax could stimulate regional growth and benefit low income groups
- Analysis of 1 cent/VMT tax in L.A.
  - Would reduce VOC, CO, NOx emissions by 4%-5% each
  - Would supplant other taxes such as special sales tax



Congestion Pricing

- Costs of driving vary with driving conditions (time of day); the price of driving should vary as well
- Accepted practice in many industries with large fixed capacity and variable demand.
  - Differential prices for telephone calls
  - Peak airfares
  - Electric Utilities
  - Early bird specials at restaurants
  - Movie matinees
- Technology no longer a barrier
  - Automated vehicle identification means no stopping for tolls which themselves create congestion and pollution
- Different kinds of pricing
  - Pricing of single facilities
  - Area-wide pricing to enter and/or exit zones

Parking Pricing

POLICY: Allow tax break for parking expenditures, but only if the employee is offered the option to receive, in lieu of parking, the fair market value of the parking in cash

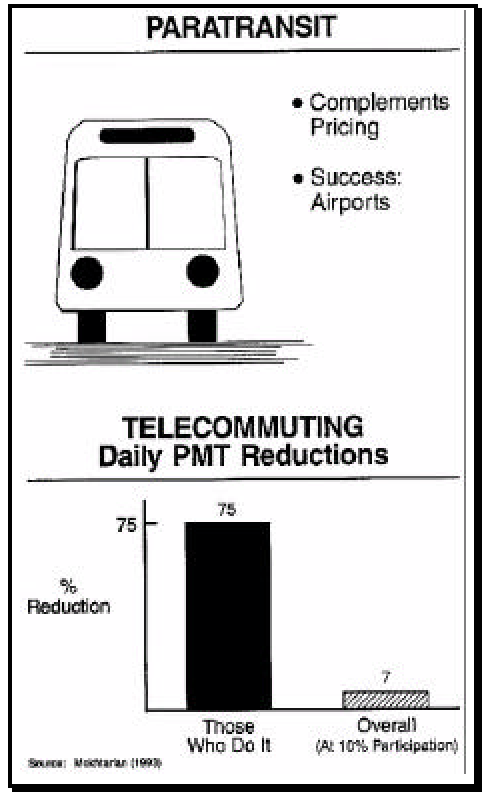
- Stimulates alternatives to peak-hour SOV
- Simple to implement at federal level
- Benefits employees by giving them choice, does not take away their fringe benefit
- Costs employers nothing, could help CBDs
- Benefits disabled, low-income employees most
- Results in voluntary tax revenue windfall

Paratransit

- Congestion pricing works in Singapore because it is accompanied by an open market for privately-operated transit
- Private paratransit works where
  - Government does not prevent it from operating
  - SOV travel is sufficiently priced
- Success: Airports
- Failure: Arizona, Downtown L.A.

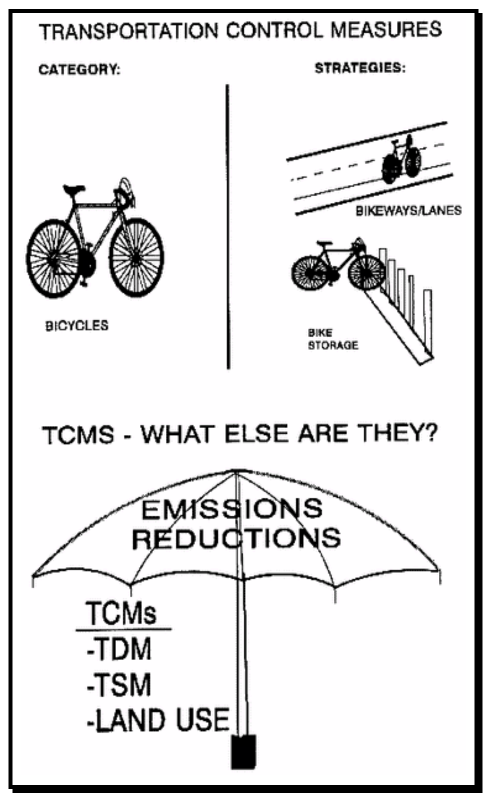
Telecommuting

- 12 million people work at home at least part-time, over half use personal computers
- Telecommuting may have already achieved a mode share roughly equal to mass transit
- Legal and regulatory barriers to telecommuting should be further examined



TCMs - What Are They?

The term Transportation Control Measure (TCM) can be defined as a transportation "related" measure designed to improve air quality by reducing the quantity of on-road mobile source pollutant emissions. This goal can be reached by reducing the amount of travel (e.g. fewer trips or vehicle miles of travel) or by reducing the rate of emissions per unit of travel (e.g. grams/VMT). Typically, TCMs focus more on altering travel behavior than on changing the emissions characteristics of vehicles through technology. However, scrappage programs of pre-1980 vehicles which is designed to remove high emitting vehicles from the fleet is included on the list of TCMs in the Clean Air Act Amendments of 1990.



The final transportation conformity regulation contained the following "official" definition of a transportation control measure: "Any measure that is specifically identified and committed to in the applicable implementation plan that is either one of the types listed in §108 of the Clean Air Act, or any other measure for the purpose of reducing emission or concentrations of air pollutants from transportation sources by reducing vehicle use or changing traffic flow or congestion conditions. Notwithstanding the above, vehicle- based, fuel-based, and maintenance-based measures which control the emissions from vehicles under fixed traffic conditions are not TCMs for purposes of this subpart."

The following example includes both the broad TCM category and several individual measures that may be selected as implementation approaches.

TCM CATEGORY	**TQM STRATEGY**
Bicycles	bikeways/lanes
	bike storage
	showers/lockers

TCMs - WHAT ELSE ARE THEY?

Transportation Control Measures in practice and in concept often overlap considerably with three other terms:

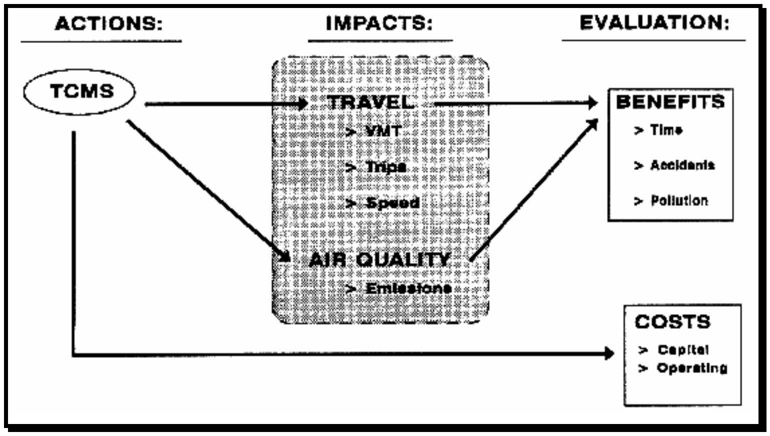
- TRANSPORTATION DEMAND MANAGEMENT (TDM)
- TRANSPORTATION SYSTEM MANAGEMENT (TSM)
- LAND USE MEASURES

All four categories can be used as tools to relieve congestion and reduce mobile source pollutant emissions. However, some specific measures in each group may increase mobility while having little or no impact on emissions. It is the commonality of their emission reduction potential that will be addressed in the module. Congestion relief or increased mobility may be a result of the actions considered in this module but are not the primary focus. Thus TDM, TSM, and Land use measures will all be considered TCMs in this course because they can reduce on-road mobile source emissions.

TCM Impact Evaluation Framework

Adjusted from " Transportation Control Measure: Which Actions Work Best?"
Douglas B. Lee, Oct. 1992.

TCM IMPACT EVALUATION FRAMEWORK



The task of evaluating TCMs in a manner that is reasonable, reliable, and defendable is not a simple assignment. Developing and following a framework on which to base the evaluation is an excellent starting point. The structure presented on the adjoining page is an example format which can tailored to fit the needs of individual areas. The basic components of the structure are described below.

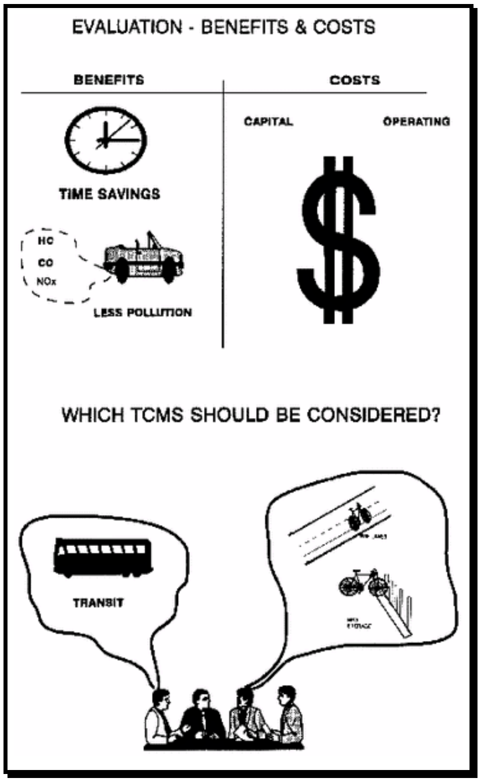
ACTIONS: Actions for TCM evaluation, are TCMs. An action could be an individual TCM or a group of several measures implemented together.

IMPACTS: Impacts fall into two categories, Travel and Air Quality. Travel impacts could include changes in VMT, trips, and speed. Air quality impacts consist of changes in the quantity and spatial/temporal distribution of emissions.

EVALUATION: Both Benefits and Costs are considered under evaluation. Benefits are the unambiguous net gains to society that result for taking one action rather than another. Costs are associated with the actions not the impacts and can include both capital and operating expenditures.

EVALUATION - Benefits and Costs

The evaluation component of the TCM framework includes both costs and benefits. Benefits of TCMs can be stated relative to a base alternative, often referred to as a do nothing alternative. It is not always necessary to quantify benefits, but they must be stated clearly. For example, stating that a measure will "improve the quality of life" or "enhance an area's mobility" is not a useful characterization of benefits for evaluation purposes.



Transportation control measure costs, like benefits, must be identified and should quantified if possible. TCMs considered in the past have generally had low capital costs relative to other projects (e.g. signal coordination versus construction of new lanes). However, in recent years both the types and magnitudes of measures being considered have expanded to include measures with high direct costs (capital and operating) and indirect costs.

In order to determine the impact a measure would have on society all the benefits and costs must be considered. However, in practice the evaluation of TCMs is often performed based on the relative cost effectiveness of various measures. The result of a cost effectiveness analysis is typically a list of measures each with their associated cost per ton of emissions reduced.

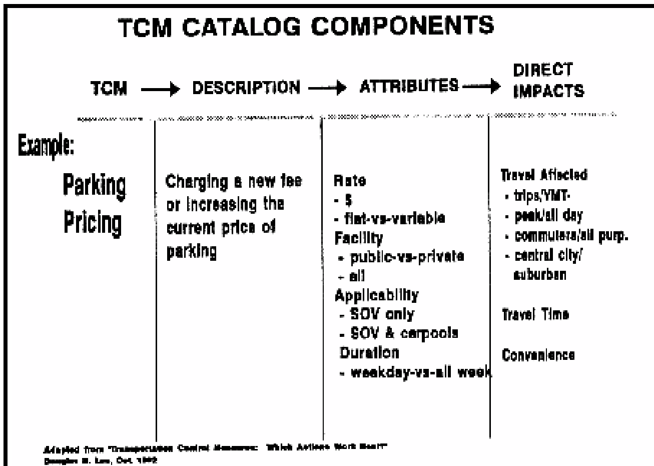
ACTIONS - Identifying Which Measures To Consider

A review of the literature reveals that volumes of information describing TCM actions is available. This information can be used to develop a large list of "Possible" transportation control measures. The list must then be narrowed to include only measures that the region is willing to consider. The result of this phase should be a list of "Potential" individual transportation control measures. It is extremely important that the selection process be designed to include public officials, interest groups, citizens, and technical staff at the earliest possible stage. If consensus building begins early then the measures that are ultimately selected will have a better chance of garnering community support.

ACTIONS - Constructing a TCM Catalog

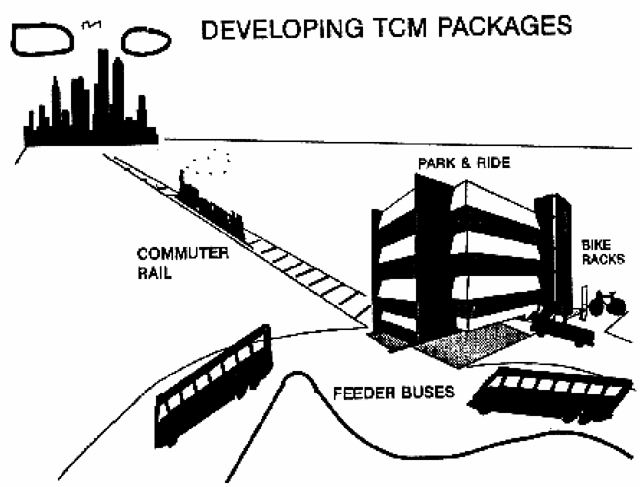
The term TCM has been used very ambiguously in the past. The expression could be used when referring to a broad category of actions (e.g. transit improvement), a very focused measure (e.g. shorter headways on suburban feeder bus routes), or almost anything in- between.

When one moves from the screening process to the analysis process it becomes very important for each action being considered to be well defined. Thus a structured list of measures, a TCM Catalog, should be generated. A TCM catalog can be developed by defining measures so that each is a type of action which can be described by a set of characteristics and attributes that can be specified from a list of parameters. Each of the actions in the catalog will have associated impacts. To ascertain a measures impact on air quality one generally must first determine the travel related impacts.



ACTIONS - Developing TCM Packages

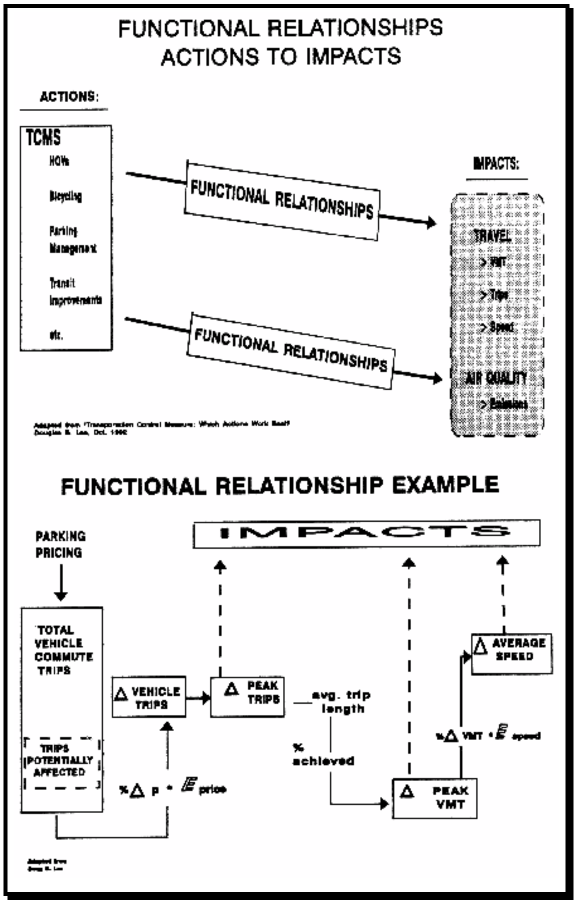
Many transportation control measures complement one another (e.g. instituting a program for parking charges and improving transit service to high employment area). These complementing measures are sometimes said to have synergy. The term synergy means that the effects of the two measures working together is greater than the sum of the effects of the individual measures. On the other hand, some measures may conflict with one another (e.g. HOV strategies and transit strategies will compete for riders.)



To obtain the greatest benefit from TCMs they should be carefully grouped into packages with individual measures designed to work together rather than merely developing a collection of individual strategies. A region's TCM program could consist of a number of packages where conflicts have been minimized and opportunities for synergistic effects have been maximized.

IMPACTS - Functional Relationship of Actions and Impacts

The objective of TCM evaluation is to determine cost effectiveness of each action so that decision makers can have the best information possible when selecting the measures to be included in the region's air quality plan. Estimating the impact of each TCM action is the critical step of the evaluation process. Actions must be identified and resulting benefits and costs have to be considered to meet this objective. However, the core component of the analysis is connection between the actions and the benefits. Note that the element that makes this linkage is composed of the travel and air quality impacts.



To determine the impact of an action one must have an understanding of the relationship between the two. These connections can be defined generically as "Functional Relationships". The diagram on the facing page depicts the idea of functionally relationships conceptually.

IMPACTS - Functional Relationship Example

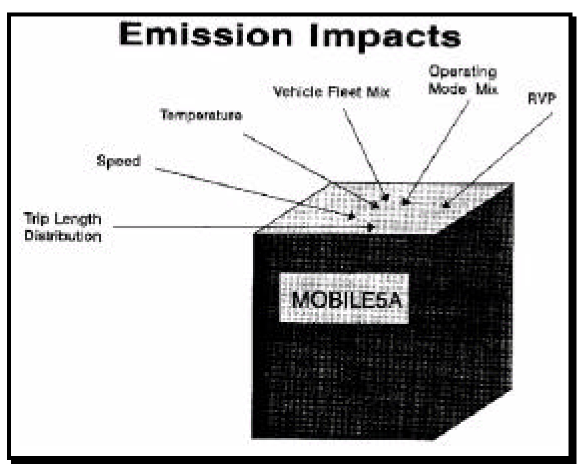
The concept of functional relationships can be expanded to show the generalized linkage between the various impacts of an action. This general form is applicable to most measures and should be used as the starting point for identifying how the analysis will be performed.

Depending on the measure a series of steps, each at a finer level of detail, may be required to accurately estimate the impacts of a measure. Ideally, the functional relationships between each TCM action (individual measure or group measures) and impacts would be clearly defined before any analysis is attempted. This would allow the analysis to focus on performing the calculations to quantify the impacts. Attempting to perform the analysis before identifying the functional relationships can result in confusion and the possible exclusion of important parameters. An example showing a relatively fine level of a detail for a measure is shown on the facing page.

Emission Impacts

IMPACT ANALYSIS - Emission Impacts

The U.S. EPA's MOBILE model is the appropriate instrument for estimating the emission impacts of TCM actions for all states except California where EMFAC can be used. The MOBILE model can be used to develop exhaust (running and idle) and evaporative emission factors for hydrocarbon emissions. Though not a direct output, the component associated with each operating mode can also be determined if required for the analysis. Additionally, MOBILE can develop exhaust emission factors for carbon monoxide and oxides of nitrogen.



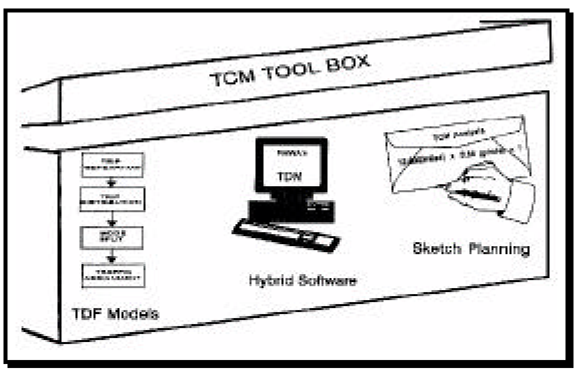
The following factors should be considered when developing emission factors for TCM analysis:

1. What portion of the day will the measure impact? If a measure is only directed at the morning peak period then a daily average temperature may not be appropriate. Similarly, a peak period speed may be appropriate for some measures, while a daily average speed may be more appropriate for others.
2. What is the pollutant of concern and during what times of the year is the measure designed to apply? Temperatures and RVP may vary by season of the year.
3. Will the measure impact the entire vehicle fleet uniformly? It may not be appropriate to use composite emission factors for all types of measures.
4. Does the measure focus on reducing a specific length of trip. For example a bicycle measure may only impact trips of less than 5 miles. This could have implications on the operating mode mix and trip length distribution input into the model.

Analysis of Travel Activity Impacts

IMPACT ANALYSIS - Travel Activity Impacts

The is no single instrument currently available which can be used to estimate the travel impacts of all TCMs at the different levels of analysis. Presently there are three primary categories of tools available for TCM evaluation:



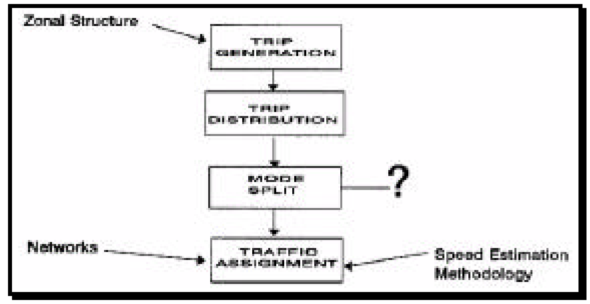
1. 4-Step Travel Demand Forecasting Models
2. Hybrid Software
3. Sketch Planning Techniques

The individual measures contained in the TCM packages may have to be analyzed using different techniques. It is, however, important to account of the interactions (conflicts and synergies) of the individual measures to the extent possible.

There are a number of factors that one should consider when selecting the tools that will be used to perform an evaluation of TCMs. The following should be four of the primary considerations:

- Level of Analysis (Screening, sketch, or detailed)
- Resources available (Time, money, data, expertise, etc.)
- Type of measure (TSM, employer based, transit improvement, etc.)
- Capability of available tools (Mode choice included In TIDF models, level of detail in modelled network, etc.)

IMPACT ANALYSIS - Travel Demand Forecasting Models



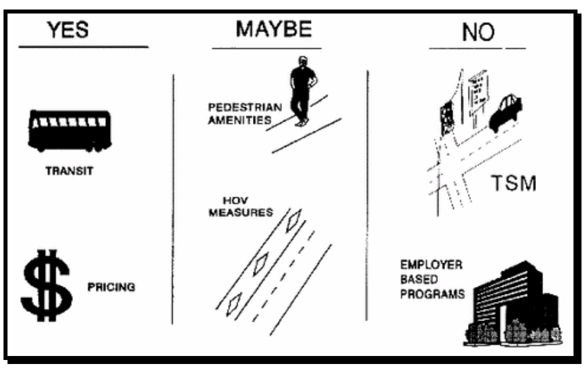
Travel demand forecasting models can be useful for TCM analysis both as a source for travel data to be used by other analysis tools and as an instrument for predicting impact of TCMs on travel. The character of a city, county, or region's models is important when determining how useful it might be for TCM analysis. Four model characteristics are of particular importance for TCM evaluation:

- Zone size
- Level of detail in highway and transit networks
- Mode choice model availability
- Sophistication of traffic assignment module

4-Step Travel Demand Forecasting Capabilities

IMPACT ANALYSIS - 4-Step Travel Demand Forecasting Models

The traditional 4-step travel demand forecasting process can be a powerful tool for TCM evaluation. Some measures can be modelled directly by the existing models, others can be modelled using surrogate variables, while still others cannot be evaluated using these models. TCMs could be grouped into the following three categories:



1. Those that can be modelled directly in the 4-step process
Examples: Pricing charges, & Transit improvements

2. Those that require extensive effort to model or must be modelled by a surrogate parameter
Examples: Transit related Pedestrian amenities & HOV measures

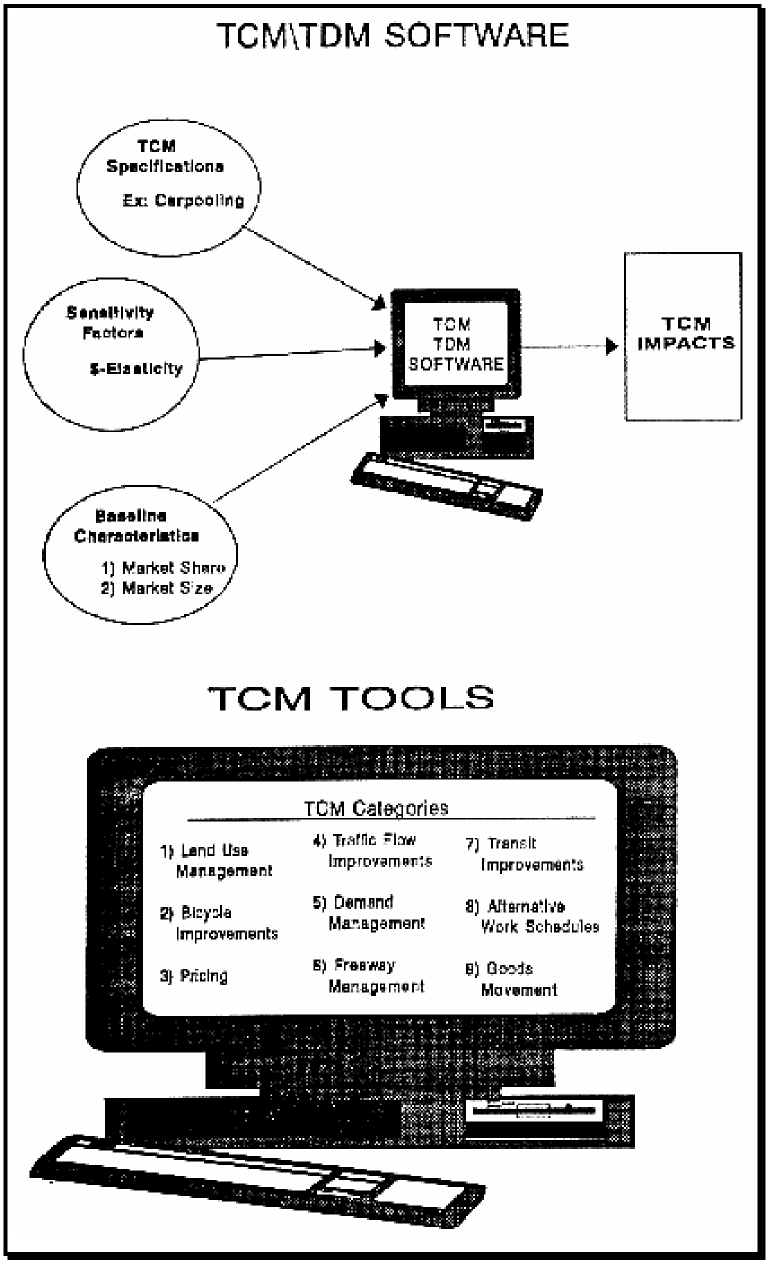
3. Those that cannot be modelled by the traditional 4-step process
Examples: TSM measures & Employer Commute Option (ECO) Programs

One factor that limits the usefulness of TDF models is the fact that they are based on traffic analysis zones. The assessment of the impacts of some TCM strategies (e.g. employer based van pooling) involves defining sub-zonal characteristics of the trips and trip makers. Thus zonal based TDF models would be inadequate for such analyses. Failure to recognize the limited geographic area of influence of some TCMs could result in overly optimistic forecasts or conversely, not detecting any impacts at all.

An additional factor that limits the usefulness of travel demand forecasting models is their reliance on "home based" information. Trip generation rates are based on household size, income, and vehicle ownership. It is difficult to translate trip reduction programs that are employer based into new trip generation rates. Neither of these factors can easily be overcome by the travel demand forecasting process in its current form.

IMPACT ANALYSIS - TCM/TDM Software

Several pieces of "Hybrid" computer software are now available that can be used in predicting the travel related impacts of transportation control measures. These programs were designed specifically to fill in some of the gaps in the TCM/TDM analysis capabilities of travel demand forecasting models. Included in this group of hybrid software packages are both TCM Tools and FHWA's TDM Evaluation Model.



These two programs were designed for distinct purposes and have different analysis capabilities. However, their basic structure is similar. Both require baseline characteristics, TCM specifications, and sensitivity factors as inputs. Each has an analysis methodology as its core. Finally, each produces estimates of TCM impacts as its output. The methodology used by the programs to handle market size, TCM specifications, and travel sensitivity factors is quite different and affects their applicability.

IMPACT ANALYSIS - TCM Tools

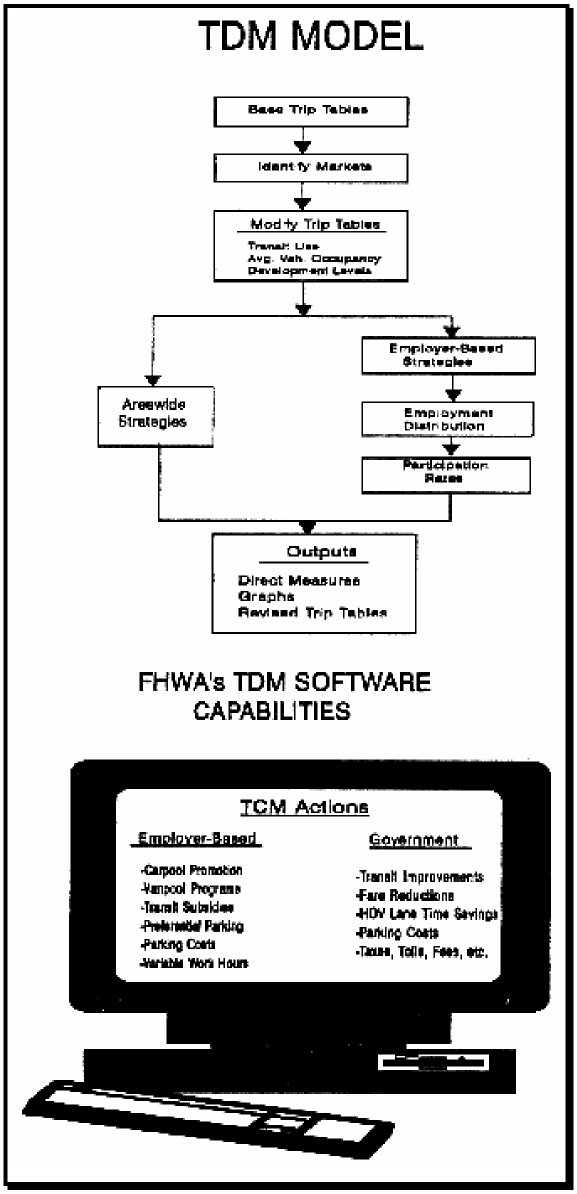
TCM Tools has three components: a travel activity module, an emissions calculation module, and a cost effectiveness module. The software was developed to be used primarily in California. So the emissions module is based on California's emissions model, EMFAC. However, the travel and cost effectiveness

modules of the software have been applied in several states. The FHWA has undertaken an effort to replace EMFAC with MOBILE5A in the emissions module so in the coming months the entire package will be applicable for use in all states.
Because of its structure TCM Tools is well suited for use as a screening tool for TCMs at a regional level. The program operates off of aggregate regional sensitivities based primarily on reported experience from California. The base travel data needed for TCM Tools can usually be obtained from regional travel models. The latest version of the model has the ability to analyze the 9 categories of TCMS including 28 measures plus two TCMs defined by the user.

The transportation module is designed to estimate the impact of each measure on trips, VMT, and speed. The software combines information on local travel, TCM specifications, and assumptions about how travelers will respond to the measure (elasticities) through a LOTUS spreadsheet. Default elasticities are included, however, they should be refined to represent local conditions.

IMPACT ANALYSIS - FHWA's TDM Evaluation Model

Overview



FHWA's TDM software was originally developed to estimate the impact of travel demand management measures on congestion. However, recently it has been used by several agencies to analyze TDM measures that have been proposed as TCMs. The TDM software is typically used in subarea analysis such as a major activity center. The model requires that a matrix of existing zone to zone trips be input along with the selection of the type and stringency level of TCM action. The trip table is then manipulated by the model to predict what changes will occur based on sensitivities obtained from past experiences. Included in these changes are mode shifts from drive alone trips to carpools, vanpools, and transit.

The model is capable of using a trip table with a maximum of 1100 zones. However, aggregating the zones into districts or reducing the regions outside the study area to external stations for a total of 15- 40 "zones" is recommend. After the changes have been made to the trip table it can be fed back into the TDF models to determine the regional impact of the measures.

Capabilities

As its name suggests the model is designed to evaluate travel demand management measures. These measures can include both government actions (e.g. transit improvements or HOV lanes) and employer-based actions (e.g. vanpool programs and variable work hours).

The primary method used by the TDM model to estimate changes in mode share is the logit pivot point procedure. The logit model is used by many MPO's to estimate mode splits within their TDF process. One property of the logit structure is that the model can be used to estimate the change in a known mode share based on changes in time or costs. Thus, TCM actions analyzed with this procedure must be translated into time and/or cost differentials. The software's default sensitivities are based on empirical data from a number of sites throughout the nation.

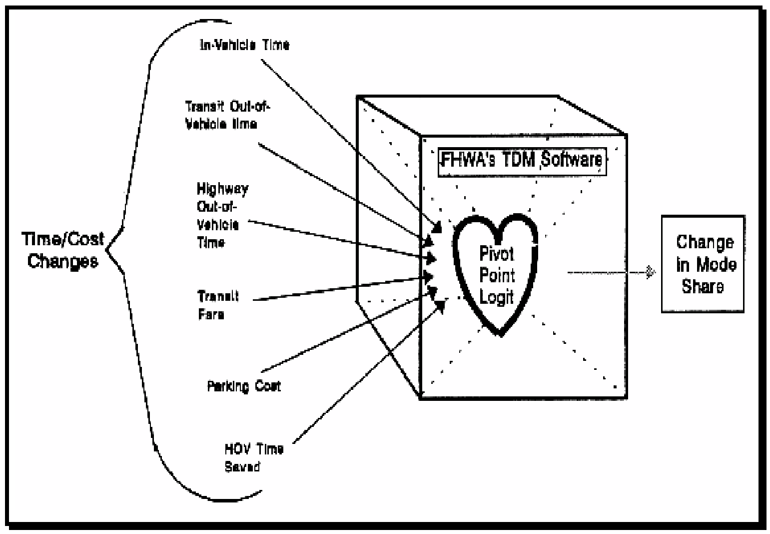
The model also has the capability of estimating the impacts of employer based programs aimed at increasing the mode shares of carpools, vanpools, and transit. The impacts are estimated based a series of look-up tables of absolute change in percent use. The tables are stratified by characteristics such as type of the employer, number of employees, and employer participation rate.

FHWA's TDM Software Model Structure

IMPACT ANALYSIS - FHWA's TDM Evaluation Model

Model Structure

The user should be aware of the following before applying this model:

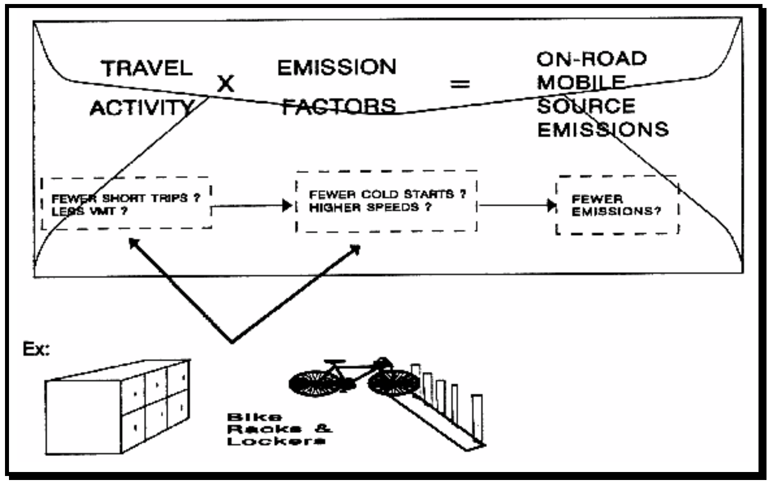


1. The model only predicts changes in mode share. Modes in a zone with a base share of zero are assumed to be nonexistent and will not show an increase in mode share no matter what is done to make the mode more attractive. To avoid this problem the user can artificially assign a very small share to the mode in the base splits.
2. The model accepts total person trips, auto driver trips, and transit trips as inputs. The program then internally calculates auto person trips and average occupancy.
3. The following are the national default disutility coefficients for the six kinds of Time or Cost changes that the TDM model is sensitive to:

Time/Cost Change	Coefficient Value
In-Vehicle Time	0.02
Highway Out-of-Vehicle Time	0.05
Transit Out-of-Vehicle Time	0.05
Transit Fare	0.004
Parking Cost	0.01
HOV Time Saved	0.10

Sketch Planning Techniques

Sketch planning techniques are appropriate when one wishes to "screen" a large group of TCMs to gain a general idea. of their potential for the region. For some TCMs sketch planning may be used for the screening step, then more sophisticated techniques may be used for later analysis steps. However, for some measures sketch planning is the only technique available for evaluating their impacts on travel and emissions.



The sketch planning methodology used for each transportation control measure is different. However, the following components must be addressed by each:

- Affected market (e.g. a bicycle measure's market may be only trips less than 5 miles occurring in the spring and fall)
- Past experience with measure (Other areas may have data)
- Trip or VMT oriented (e.g. Telecommute centers may result in the same number of vehicle trips but they will be shorter)
- Potential for synergy/conflict with other measures Costs (How much and who will pay?)
- Related data availability (e.g. How many intersections could safely allow right turn of red?)

Workshop on Assessing TCM Impacts

TCM Workshop Travel Demand Forecasting Example

A transportation control measure has been proposed for the Washington, D.C. region that would require all federal work sites to charge the equivalent of commercial parking rates. All federal employees who drive would be required to pay the full commercial rate for parking. It is assumed that since the requirement applies only to work sites, there will be no effect on non-work trips.


The Washington Times

Free federal parking on local hit list

Fees, subsidies proposed to boost mass transit, improve air quality

PARKING

This proposed measure has come to the attention of Vice-President Al Gore. He is considering including it in the plan to reinvent government. As a transportation planner who has been detailed to the reinventing Government task force you have been assigned the task of estimating the change in trips, vehicle miles of travel, and emissions resulting from this proposed measure.

The Vice-President recognizes that many of the federal workers who would be affected by this action may not be very supportive of this particular measure. Believing that many federal employees are concerned about the environment, Mr. Gore thinks that demonstrating the air quality benefits of the proposed action will garner their support for the measure. However, he also believes in backing up his ideas with strong analytical evidence. Therefore, he has asked you to provide example calculations showing the procedures used to estimate the air quality benefits of the measure. The analysis for this measure has already been performed for the entire Washington, D.C. region. The calculations shown in the following steps are based on one of the impacted traffic analysis zones (Zone 1). Completion of these steps should provide the Vice President with the documentation he needs.

DATA AND ASSUMPTIONS FOR ESTIMATING THE IMPACT OF THE FEDERAL PARKING CHARGE TCM

PARKING DATA

1. Data from a recent parking survey show that 18% of the employee parking spaces in the zone are for federal workers and 82% are for non-federal workers. The data from that survey are shown on the facing page.
2. The base average parking rate (APR) for zone 1 was estimated to be 58 cents in 1980 dollars based on data provided Washington Metropolitan Council of Governments (WashCOG). The base APR is an average that includes those who pay the full commercial rate, those parking at subsidized rates, and those parking for free.
3. The market rate for parking is the amount paid each day by those not receiving a subsidized parking rate (i.e. the full commercial rate). WashCOG's mode choice models were developed based on the average parking rate for each zone. So the base APR of 58 cents was used to calculate the daily market rate for parking in zone 1 that is built into the models. The result was a rate of 107.5 cents per day.

ASSUMPTIONS

1. This TCM will only affect Federal parking spaces. So after the measure 100% of Federal spaces will be charged the full market rate.
2. The discount parking rate is ½ the full market rate or 53.75 cents.
3. The original mode shares for zone 1 are as follows:
   Drive alone = 50.4%
   Carpool = 26.5%
   Transit = 23.1 %
4. The carpool occupancy rate is 2.45.

Base Parking Data

Step 1 Calculate the "new" average parking rate for the zone.

The "new" average parking rate in zone 1 can be determined using the equation shown below with the assumption that all federal spaces will now be provided at the full market rate. This new APR will reflect the impact of the TCM on the average parking rate for zone 1 now that 100% of the Federal spaces will be provided at the full market rate.

PARKING SPACES: (zone 1)	
	FEDERAL = 18%
	NON-FEDERAL = 82%

PARKING COST: (Region)	Percent Paying						
	FREE		DISCOUNT		MARKET RATE		
Federal	74%	+	22%	+	4%	= 100%
Non-Federal	30%	+	15%	+	55%	= 100%

APR' = %FED(%FD * M/2 + %FF * M)+%NONFED(%NFD*M/2 + %NFF * M)

Where:

APR'	=	New average parking rate in a zone
M	=	Market parking rate for the zone
%FED	=	Percent of total parking spaces that are for federal employees
%FD	=	Percent of the federal spaces that are provided at a discount rate
%FF	=	Percent of the federal spaces provided at full market rate
%NONFED	=	Percent of total parking spaces that are for non-federal employees
%NFD	=	Percent of non-federal parking spaces provided at a discount rate
%NFF	=	Percent of non-federal spaces that are provided at full market rate

Complete the calculations on the facing page to solve the above equation to determine the new APR:

NOTE: *The discounted rate is assumed to be ½ the full market rate or 53.75 cents.

Calculate New APR

Step 2 Calculate the effect of parking rate change on logit utility values.

It would not be practical or wise to burden the Vice-President with the many pages of calculations that would be required to duplicate the methodology used by WashCOG's mode choice model for estimating the new mode shares that would result from this transportation control measure. Therefore, the logit pivot point procedure will be used to provide a general sense of how the mode choice model calculates changes in mode share. Two inputs are required to use the logit model for this purpose, the change in utility of each mode and the original mode share for work trips attracted to zone 1.

Original Mode Shares

The following original mode shares (P(m)) for work trips attracted to zone 1 were estimated using the mode choice model:

Percent Paying		RATE (cents)		WEIGHTED RATE
0%	X	53.75	=	0.0
0%	X	0.0	=	0.0
	X		=	
	X		=	
	X		=	
	X		=	
		Sum is New APR	=	

- Drive alone = 50.4%
- Carpool = 26.5%
- Transit = 23.1%

Changes in Utility (U)

The changes in utility (U) can be calculated by multiplying the logit coefficient(.0094 - obtained from the mode choice model) by the change in the travel characteristic (e.g. average cost to park per person). Three modes are considered: drive alone, carpool (2.45 is the average carpool occupancy), and transit. This measure addresses parking pricing only so there is no change in the transit utility.

The first step in calculating the changes in utility is to determine the change in the average parking rate for the zone. For this example the change in the average parking rate for zone 1 can be calculated by subtracting the base APR from the new APR. The change in average parking cost for zone 1 is

74.4 cents - 58 cents = 16.4 cents

Now calculate the change in utility for the three modes caused by the change in the average parking cost for the zone. Use the equations on the facing page (carry the calculations out to 4 decimal places).

Calculate Change in Utility

△ U(drive alone) = 0.0094 X Change in average parking cost for zone 1

[ ] = 0.0094 X [ ] cents

△ U(carpool) = 0.0094 X Change in average parking cost for zone 1 / auto occupancy

[ ] = 0.0094 X [ ] cents / [ ]

△ U(transit) = 0.0000

Step 3 Calculate New Mode Shares

Now that the change in utility and the original market share are known for each mode, the new mode shares can be estimated. The pivot point procedure is applied using the following equation for the logit model as a basis for the calculations:

$$P'(m) = \frac{P(m) * e^{[-ãU(m)]}}{P(m1) * e^{[-ãU(m1)]} + P(m2) * e^{[-ãU(m2)]} + ... + P(mi) * e^{[-ãU(mi)]}}$$

Where:

P'(m) = the new mode share for mode m
P (m) = the base mode share for mode m
m = mode (drive alone, carpool, transit)
ãU(m) = the change in the utility of mode m
e_x_ = the exponential function (e to the power x, where e = 2.7183...)

NOTE: (The U's are multiplied by -1 because here, they represent disutility. The higher the disutility. the less likely the mode is to be used.)

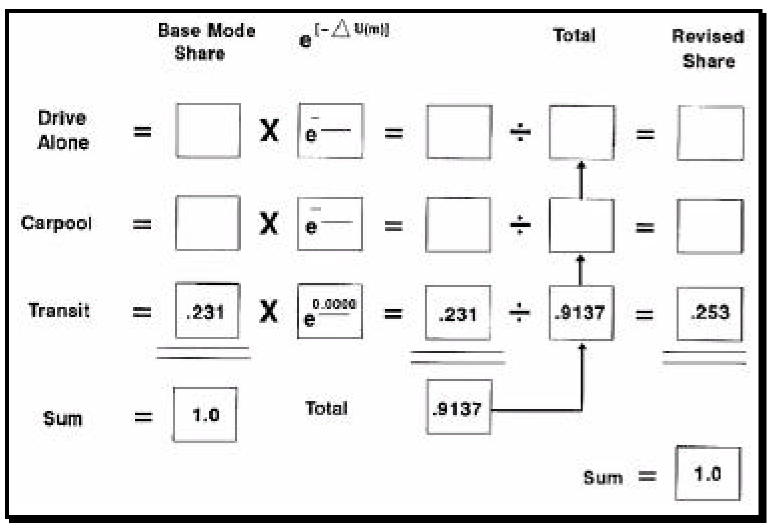
Complete the calculations on the facing page (based on the equation shown above) to determine the revised share for each mode (Use the utility values calculated in step 2 as the exponent for e):

This completes the example calculations for Zone 1. The final steps are based on the impact of the TCM on entire region.

Calculate Revised Mode Shares

Step 4 Calculate the travel impact of the TCM for the entire Washington, D.C. Region

The calculations that were made in the previous steps for Zone 1 were performed by the WashCog travel demand forecasting models for all zones in the Washington, D.C. region. The changes in mode share resulted in significant changes in travel. The data shown below are estimates of Home-Based Work vehicle trips and vehicle miles of travel that resulted from the model runs made for the entire Washington, D.C. area.



Calculate the total HBW VT and VMT reductions for the region.

	HBW Vehicle Trips	HBW Vehicle Miles of Travel
Base	3,184,233	47,005,634
New(reflects impact of 3,146,262 new parking cost)	46,502,588	
HBW VT reduced =	HBW VMT reduced =	

The mode choice model only estimates home-based work travel. However, some trips that are linked to the home-based work trips may be eliminated as well. It is estimated that the total portion of trips and VMT reduced by this measure would be 1.155 times the HBW travel reductions.

Given these HBW travel reductions and the correction factor for additional travel effects, calculate the total VT and VMT that would be reduced by the proposed measure.

HBW Reduction		Correction Factor		Total Reduction
VT	*		=	
VMT	*		=	

Step 5 Calculate the Emissions Impacts of this TCM for the entire Washington, D.C. Region

The final step is to utilize the estimated total VT and VMT reductions to determine the transportation control measure's impact on emissions. The following emission factors were produced by WashCOG using MOBILE5A Volatile Organic Compounds:

Start factor(S): 2.919 grams/trip
Running factor(R): 0.551 grams/mile
Hot soak factor(H): 1.114 grams/trip

Complete the following to estimate the reduction in VOC emissions resulting from the implementation of this TCM:

Emission Factor Travel Value			Emission Reduction
Starts:	x	=	grams
Running:	x	=	grams
Hot Soaks:	x	=	grams
Total		=	grams

$$\text{Total Regional Reduction} = \frac{\text{Total (grams) *}}{\text{908175 tons}} =$$

NOTE: The Start and Hot soak factors are associated with each trip. However, the running factor is associated with the vehicle miles of travel.

* Grams of emissions can be converted to tons of emissions by dividing by 908175.

GLOSSARY OF KEY TERMS AND ABBREVIATIONS

ADT - Average Daily Traffic

Alternative modes - Transportation modes other than one person in a motorized private vehicle, such as transit, walking, bicycling or carpooling.

Alternative work schedules - TCM to encourage commuters to travel to and from work outside the peak hours or periods, and possibly fewer days per week.

AQAP - Air Quality Attainment Plan. Plan written to demonstrate how a region will attain air quality standards.

Area Sources - A combination of emission sources that are individually small, but collectively significant (e.g. gas stations, dry cleaners).

Arterial - As used in this document, an arterial is a roadway that serves major traffic movements, and secondarily provides access to abutting land (precise definitions vary among localities and states). Arterials generally carry higher traffic volumes at higher speeds than collectors and local streets, but carry lower volumes at lower, speeds than expressways, freeways, and other limited access and grade separated facilities. Arterials may be designated either principal (also called major) or minor, with principal arterials placing relatively more emphasis on service to through traffic, and carrying higher volumes, possibly at higher speeds. Principal arterials are frequently served by public transportation; minor arterials may also carry bus traffic. Regional highway networks for urban areas should include all arterials.

ASTM - American Society for Testing and Materials

Attainment - Have pollutant concentrations less than the specified standard.

AVR - Average Vehicle Ridership. The average number of people arriving at a sight divided by the number of vehicles.

BARCT - Best Available Retrofit Control Technology

Baseline travel characteristics - A collection of data that are used to describe the characteristics of travel in a given area.

Bicycling program - A TCM implemented to accommodate the use of bicycles as an alternative to motorized transportation.

Carpool - Two or more people traveling in a private vehicle.

Catalytic converter - A device which removes certain pollutants from vehicle exhaust through catalytic adsorption.

CBD - Central Business District

CCAAs - Clean Air Act Amendments of 1990

CFR - Code of Federal Regulations

CMA - Congestion Management Agency

CMAQ - Congestion Mitigation and Air Quality

CMP - Congestion Management Program

CMS - Congestion Management System

CO - Carbon monoxide

Cold start - The starting of an engine which is significantly below normal operating temperature, of significance in understanding vehicle emissions because the rate and composition of emissions vary with engine temperature. Cold start mode, the period of operation to which cold start emissions rates apply, is defined by EPA for catalystequipped vehicles as the first 505 seconds after start of an engine which has been turned off for one hour or more (four hours for non-catalyst-equipped vehicles).

Collector - An urban street which provides access within neighborhoods, commercial, and industrial districts, and which channels traffic from local streets to minor and major arterials. Collectors are typically low volume and low speed streets; however, they sometimes serve local bus traffic. Collectors meeting this definition are not usually explicitly represented in regional highway networks.

Compressed work week - A TCM that encourages employees to work their normal number of hours in less than five days per week or in less than 10 days in two weeks.

Conformity - In general, the agreement of transportation plans and programs with assumptions and commitments designed to attain federal and state air quality standards. Specifically, conformity to a SIP means conformity to the plan's purpose of eliminating or reducing the severity and number of violations of the national ambient air quality standards (NAAQS).

Congestion - Interference of vehicles with one another as they travel, reducing speed and increasing travel time. Travel time on a link increases as an exponential function of the ratio of the number of cars on the link (volume) to the link's capacity.

Cost-effectiveness - Cost per unit of a measure of effectiveness (e.g. tons of pollutant reduced).

Dispersion model - A model which estimates atmospheric concentrations of pollutants as a function of emissions rates and in some cases, emissions locations, meteorological factors, and rates of chemical reactions that may occur. Three common types of dispersion models have been used: 1) methods applying the continuity equation of physics to describe physical and chemical processes that govern (Emissions - concentration relationships, 2) methods using a probabilistic description of the motion of pollutant particles to derive estimates of concentrations, and 3) methods that use statistical relationships between emissions and concentrations to infer future relationships.

Diurnal emissions - Vehicular emissions that occur on a daily cycle, and are not necessarily related to vehicle use (through usage patterns may affect diurnal emissions rates). As of this writing, diurnal emissions factors are available for evaporative hydrocarbon emissions only.

DMV - Department of Motor Vehicles

DOT - U.S. Department of Transportation

Dynamometer - An apparatus for measuring mechanical force such as that produced by an engine, used in conducting tests of fuel consumption and emissions rates of vehicles. Dynamometers allow testing of vehicles under replicable and controllable conditions, but such tests often produce estimates of fuel consumption and emissions rates below those measured under field conditions, because it is not easy to replicate the complexity of actual driving patterns in an artificial environment. Dynamometer tests conducted under the standard Federal Test Procedure (FTP) are known not to faithfully simulate driving conditions involving accelerations associated with especially high emissions rates (so called "off-cycle" accelerations).

EMFAC - EMFAC is a computer-based mathematical model used to calculate motor vehicle emissions, for use in California. EMFAC7F is the version current in July 1993.

EPA - U.S. Environmental Protection Agency

FHWA - Federal Highway Administration

FIP - Federal Implementation Plan

Fixed-route transit - Transit services with regular established routes and schedules. Other types of transit might be demand-responsive or door-to-door services.

FTA - Federal Transit Administration

FTP - Federal Test Procedure

Functional classification - The classification of urban roadways by function. Roadways at the top of the hierarchy serve intercity and other long-distance movement of traffic, roadways at the bottom provide access to land. Traffic volumes and spacings typical of each level in the hierarchy are as in the table below.

HC - Hydrocarbons

HDDV - Heavy duty diesel vehicles

HDGV - Heavy duty gasoline vehicles

HPMS - Highway Performance Monitoring System

Hot-soak emissions - Emissions which occur after a hot engine is turned off.

Hot-spot - A location with higher-than-ambient levels of a pollutant. Hot spots may be attributed to such things as weather patterns, topography, and traffic intensity.

Hot-start - In vehicle emissions analysis, it results in lower emissions than from a cold start. A hot start occurs when a vehicle's engine is started after less than an hour of rest from the previous period of operation (four hours for non-catalyst-equipped vehicles).

HOV - High-occupancy vehicle

HPMS - Highway Performance Monitoring System, a federally-mandated database consisting of a representative sample of highway links.

I/M - Inspection and Maintenance

Impact fees - Fees assessed on a development in anticipation of expected impacts.

Incorporated - Areas that fall under city/town as well as county jurisdictions.

Indirect sources - Any facilities, buildings or installations that generate or attract mobile source activity that results in emissions of air pollutants.

ISRR - Indirect Source Review Rule

ISTEA - Intermodal Surface Transportation Efficiency Act

Jurisdiction - Governing bodies with control over specific issues.

kg - Kilogram

km - Kilometer

LDDT - Light duty diesel trucks

LDDV - Light duty diesel vehicles

LDGT1 - Light duty gasoline trucks1

LDGT2 - Light duty gasoline trucks2
LDGV - Light duty gasoline vehicles

LEV - Low Emission Vehicle. A vehicle that has emissions lower than the standard combustion engine, usually due to the use of alternative fuels.

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).

MC - Motorcycles

MOBILE5A - The latest version of EPA's mobile source emission factor model.

Mobile source - A moving source of emissions, including but not limited to motor vehicles.

MOU - Memorandum of Understanding

mph - miles per hour

MPO - Metropolitan Planning Organizations

Multimodal stations - Stations that facilitate the link between modes of transportation.

NAAQS - National Ambient Air Quality Standard

Neighborhood work center - A work location closer to where employees live, similar to a satellite work center, but is shared by employees from a number of different companies.

NHS - National Highway System.

Non-attainment area - An area that does not achieve one or more federal national ambient air quality standards.

NOx - Oxides of Nitrogen

NTPS - Nationwide Personal Transportation Study

Off-peak period - Periods of lower traffic volume, the hours between peak periods.

Ozone - The O3 form of oxygen, a regulated pollutant and a key component of smog.

Park-and-ride lots - Allow commuters that do not have convenient access to alternative transportation modes to drive to lots, park their cars, and use transit or join a carpool\vanpool for the remaining portion of their commute.

Passenger rail - Rail service oriented towards carrying passengers rather than cargo.

Peak period - Periods of heaviest traffic volume, usually a cyclical bimodal pattern on weekdays reflecting direction of commuter traffic flow.

PCCC - Catalyst cold-start

PCCN - Non-catalyst cold-start

PCHC - Catalyst hot-start

Ridesharing - A TCM in which employers or agencies provide carpool\vanpool information and incentives.

ROP - Rate of Progress.

RVP - Reid Vapor Pressure

Satellite work center - Resembles a branch office of the larger organization at a location that is closer to where the employees live.

SIP - A State Implementation Plan developed under the Federal Clean Air Act to improve air quality.

SMSAs - Standard Metropolitan Statistical Areas

SOV - Single Occupant Vehicle.

TDF models - Travel Demand Forecasting Models

TDM - Travel Demand Management

TSM - Transportation System Management

UAM - Urban Airshed Model

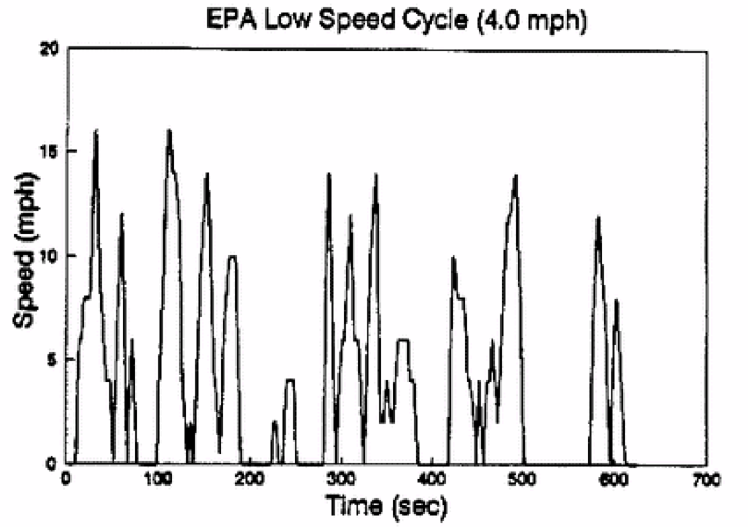
v/c - Volume to capacity ratio

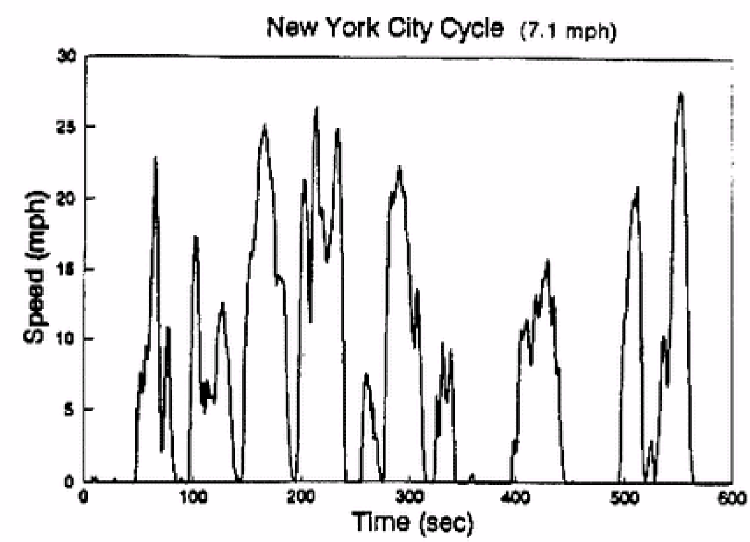
VMT - Vehicle Miles of Travel

VOC - Volatile Organic compound. VOC emissions, also known as hydrocarbons (HC) or reactive organics (ROG), are major ingredients of smog.

ADDITIONAL DRIVE CYCLE PROFILES

Speed-Time Profiles of Cycles Used in Speed Correction Factor Development





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HHI-10/2/95 (400)

PARTICIPANT EVALUATION OF TRAINING

Interim Workshop on Transportation Air Quality Analysis

Please help us to Improve the Training by evaluating the training course and workshop in which you participated. Your input is appreciated and needed. You may use the back of this form for additional comments.

What parts of this program were most helpful to you? Why?

Indicate topics which should be added or discussed in more detail.

We welcome any additional comments you have.

Please rate this training session overall on a 10 to 1 scale (10 good - 1 bad)
10 9 8 7 6 5 4 3 2 1

Additional comments regarding this training, other desired training, etc, are welcome. Contact us at (202) 366-0182 or send your suggestions to Federal Highway Administration, Metropolitan Planning Division, HEP-22, Room 3232, 400 Seventh Street, SW, Washington, DC 20590. Thank you for taking the time to share your opinions and ideas.

Name Telephone

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