United States
Environmental Protection
Agency

Air

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EPA-452/R-93-003
January 1993

EPA

ISSUES AND APPROACHES TO IMPROVING TRANSPORTATION MODELING FOR AIR QUALITY ANALYSIS

ISSUES AND APPROACHES TO IMPROVING TRANSPORTATION MODELING FOR AIR QUALITY ANALYSIS

OFFICE OF AIR QUALTITY PLANNING

AND STANDARDS

and

OFFICE OF MOBILE SOURCES

U.S. ENVIRONMENTAL AGENCY

JANUARY 1993

Notice

This material has been funded by the United States Environmental Protection Agency (EPA) under contract 68D00102, Assignments 2-16 and 3-08 to Systems Applications International (SAI) and the Urban Analysis Group (UAG). Significant technical material was developed by SAI personnel including Julie Fieber, Lori Duvall, and Doug Eisinger. For UAG, Edward Granzow, and Jo Ann Coxey made significant contributions. Sharon Reinders of the Office of Air Quality Planning and Standards and Mark Wolcott of the Office of Mobile Sources served as co-Work Assignment Managers of the project. Ted Creekmore assisted with the final review and publication. This document has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Executive Summary

Driven in large part by passage of the Clean Air Act Amendments (CAAA) of 1990, increased attention and resources have been directed towards improving the procedures of transportation modeling in order to arrive at information better suited for air quality analyses. Several studies sponsored by the EPA, national organizations, and state and local agencies have been initiated in the last two years to try to improve transportation modeling. This report documents the results of one of these efforts. The purpose of this work was to produce a list of current shortcomings both in transportation model structure and in the ways transportation models are used, written in large part from the perspective of air quality modelers. The intention has been to provide a document which would be of use to both transportation and air quality modelers. In addition, a list of improvements to either the models or transportation modeling procedures, augmented by sample model runs demonstrating implementation of some of these suggestions, is provided.

Contents

92004r1 01

92004r1.01

1 INTRODUCTION

BACKGROUND

This document has been prepared to explain to transportation modelers the detailed input requirements of air quality analyses and to explain to air quality modelers ways in which the current practices in transportation modeling may not always be well-suited for providing these inputs, largely because of data limitations. Some suggestions, largely relating to improved communication between transportation and air quality personnel, are made. An example of one suggestion explored in this document is focusing more attention on the assumptions used in modeling intrazonal travel. Transportation models were not designed for explicitly treating this type of travel and yet from an air quality perspective it is important. Many of the other suggestions offered in this document are actually post-processing steps, intended to incorporate more detail into the vehicle emission inventories prepared from transportation model outputs. As an example, we have included an example of one procedure which illustrates the importance of properly matching fleet mix to road type when determining what average fleet emission rates should be used with the vehicle activity estimates produced by transportation models. Suggestions are included that are appropriate for areas with preexisting transportation models as well as for areas that are beginning development of a transportation model or that are in the process of updating a preexisting transportation model.

Transportation demand analyses can be envisioned as comprising four steps: the estimation of trip generation, trip distribution, mode choice, and trip assignment. These four steps are often referred to as the "urban transportation planning, or modeling system" (e.g., see Meyer and Miller, 1984). Computer models or manual procedures, such as sketch planning methods, exist as tools for transportation demand analyses (SAI, 1989). There is great variety in the approaches available for transportation demand analyses.

Both transportation and vehicle emission models have a variety of uncertainties and difficulties associated with their use. Generally, both provide better results on a macro rather than microscale basis. Thus, transportation models are likely to be more accurate at predicting total VMT on a county-wide basis than at the level of individual links, and vehicle emission factor models are better at developing regional emission estimates than estimates for a particular intersection.

Transportation models are generally designed for the evaluation of urban transportation needs and network designs. This type of use does not require the same type of detailed transportation activity data as is required when developing emission inventories for air quality analysis. For example, an air quality analysis might require seasonal, day-of-week, and/or hourly estimates of travel activity (including average speeds) in order to properly account for the effects of temperature on vehicle emission rates or to develop vehicle emission estimates that reflect travel behavior on a specific day or portion of day. Spatial allocation of vehicle miles traveled and even trip starts and trip ends is typically required when conducting an air quality analysis. Typical transportation models are not designed to provide such detailed information, yet information developed in the transportation modeling process can help supply the data needs of air quality modelers. For example, though it is generally unreasonable to attempt to survey traffic and run transportation models on an hourly basis, it is reasonable to use the models to provide predictions of peak and off peak travel activity, and even to differentiate between morning and afternoon peak periods. Interpolation can then be used to estimate hourly travel activity. Most transportation models are already capable of providing estimates of travel activity by roadway link and estimates of trip starts, trip ends, and intrazonal travel by zone, thus providing the detailed information on the spatial distribution of travel required for air quality analysis.

ORGANIZATION OF THE REPORT

The focus of Chapter 2 of this report is to describe the specific requirements placed on transportation models to provide necessary inputs for air quality analyses, and some of the qualities of the current generation of transportation models which limit their use in air quality analyses. Chapter 3 develops these ideas further through a list of questions which should be discussed between transportation and air quality modelers regarding each of the four steps of the transportation modeling process. The goal is to improve the air quality modeler's understanding of the relative strengths of vehicle activity estimates produced by transportation models. Finally, in Chapter 4 procedures are suggested for tailoring the results of transportation model exercises more specifically for air quality analysis, accompanied by results from sample model runs which demonstrate a few of these suggestions.

It should be noted that some of the issues of concern with transportation modeling discussed in this report will generally be of most importance if model predications are used to prepare modeling inventories for urban-scale air quality models, such as the Urban Airshed Model (UAM). Such applications are often required for areas that have not attained ozone and carbon monoxide standards. Not every air quality analysis needs to have as detailed information on the temporal and spatial distribution of vehicle activity as is needed for photochemical grid models like the UAM; sometimes annual regionwide estimates are sufficient. The suggestions included in this report should, in general, result in the more accurate representation of vehicle activity for these applications as well as for the production of modeling inventories.

2 TRANSPORTATION MODEL SHORTCOMINGS WITH RESPECT TO EMISSIONS

This chapter sets out a description of what is required from transportation models in order for air quality personnel to develop vehicle emission inventories. This is followed by a discussion of areas where travel demand models do not perform as well as needed for emission inventory development, and what the implications of these model limitations are for emission estimates calculated with travel demand model output.

DEVELOPMENT OF AIR QUALITY MODELING INPUTS FROM TRANSPORTATION MODELS

In the past, air quality control strategies were based on relatively simple emission inputs; generally county-wide annual average seasonally adjusted emissions. However, the Clean Air Act Amendments (CAAA) of 1990 have required that some regions use photochemical grid modeling, which places more stringent demands on emission inputs. The primary requirements of the emission inventory to be used in grid modeling can be summarized in the following manner:

> Estimates of precursor pollutants must be provided for each individual grid cell of a modeling domain rather than at a county level; these may be as small as 2 km × 2 km.
>
> Hourly emission rates must be provided instead of annual average emissions. Note that estimates of peak and off-peak period travel activity provided by most transportation models can be used to estimate hourly travel activities without resorting to the collection of hourly data.
>
> Total organic gas (TOG) emissions must be disaggregated into individual chemical classes corresponding to the chemical mechanism of the photochemical model.

The emission factors used to estimate emissions from on-road motor vehicles vary non-linearly with a variety of parameters, including vehicle type, vehicle speed and acceleration, fuel volatility, vehicle fleet characteristics, ambient temperature, diurnal temperature variations, and vehicle fleet inspection program characteristics. These emission factors (which are usually reported in terms of grams pollutant/vehicle mile or event) are then used with an activity level (e.g., VMT or number of events) to generate on-road vehicle emissions estimates. Ideally, link-specific traffic parameters will be used to generate the emission estimates in order to retain information on the spatial distribution of emissions. Various inventory classification schemes may then be employed to aggregate these emissions into a manageable number of categories; two examples include vehicle class and road type.

To properly understand the requirements placed on transportation models for developing relatively accurate inputs for air quality analyses, an understanding of motor vehicle emission rates is useful. The following discussion briefly describes the parameters which affect mobile source emission estimates. The elements discussed are emission components, vehicle classes, roadway classifications, spatial distribution, and temporal distribution. Areas where information either is currently or could be supplied by transportation models are indicated in the discussion.

Mobile Source Emissions

Mobile source emissions should be disaggregated into their components in order to properly distribute them spatially and temporally, and in order to properly speciate the hydrocarbon emissions. The individual components of the on-road vehicle emissions are defined below:

> Exhaust emissions: vehicle tailpipe TOG, oxides of nitrogen (NO_x), carbon monoxide (CO), particulates, and oxides of sulfur (SO_x) emissions which occur during the operation of the vehicle. These emissions occur along transportation links, and are highest during peak vehicle operating hours.
>
> Evaporative emissions: TOG emissions which include diurnal emissions, resting losses, and hot soak emissions. Diurnal emissions result from fuel vapor expansion occurring during periods of rising ambient temperatures. Resting losses occur due to fuel vapor permeating through fuel lines, loaded canisters, and liquid leaks. Hot soak emissions consist of the evaporation of fuel by engine heat immediately following the end of a trip. All are associated with stationary vehicles, and their amount is a function of fuel volatility, and ambient temperature.
>
> Running loss emissions: evaporative TOG emissions that occur during the operation of the vehicle. These emissions also occur along transportation links, and are highest during peak vehicle operating hours.

Exhaust and evaporative emissions must be differentiated because of the different TOG species profiles (which affect ozone production and toxicity) for these two categories, and because the spatial distributions of these emission modes are different. Exhaust emissions occur primarily along roadways; evaporative emissions, because they occur while a vehicle is parked, occur primarily in residential or business districts.

As mentioned throughout this report, the vehicle emission rates for all of these emission modes are strongly dependent upon temperature and, for exhaust and running loss emissions, vehicle speed. For example, the temperature dependence of light-duty vehicle emission rates is demonstrated for total organic gas (TOG) emissions in Figure 2-1, and the speed dependence of CO emission rates in Figure 2-2.

Vehicle Classes

The registered vehicle fleet can be divided into sub-groups, or classes, such as autos, light-duty trucks, and heavy-duty trucks. The emission factors associated with each vehicle class vary widely because of differing emission certification standards and pollution control equipment. For example, the MOBILE model (EPA, 1991) distinguishes eight vehicle classes, listed in Table 2-1, based upon gross vehicle weight (GVW) and fuel type (gasoline or diesel). Inventories will typically use some combination of these eight vehicle classes to report emissions, such as LDGV, LDGT, HDGV, and HDDT.

Currently, transportation models do not report VMT by vehicle type. In order to estimate emissions, assumptions must often be made to disaggregate VMT and trip ends by vehicle type, and a way found to distinguish between commercial traffic, transit buses, and fleet operations. For some purposes, VMT associated with alternative fuels must also be disaggregated.

Roadway Types

On-road mobile source emissions should also be distinguished by road type in the inventory. Some of the road types for which the Federal Highway Administration (FHWA) maintains statistics are listed in Table 2-2; these road types are commonly used in mobile emission inventories. Emission factors will vary by road type because of changes in speed and fleet distributions associated with different road types.

For example, a rural or urban interstate might be preferentially used as a transportation route for trucking operations, or for the movement of farm products during harvest periods. Hence, under such conditions, one might expect a higher concentration of heavy-duty diesel vehicles on this roadway type, which would cause the fleet distribution to be markedly different from that which would be found on roadway types which are used more for commuter traffic, such as urban collector roadways.

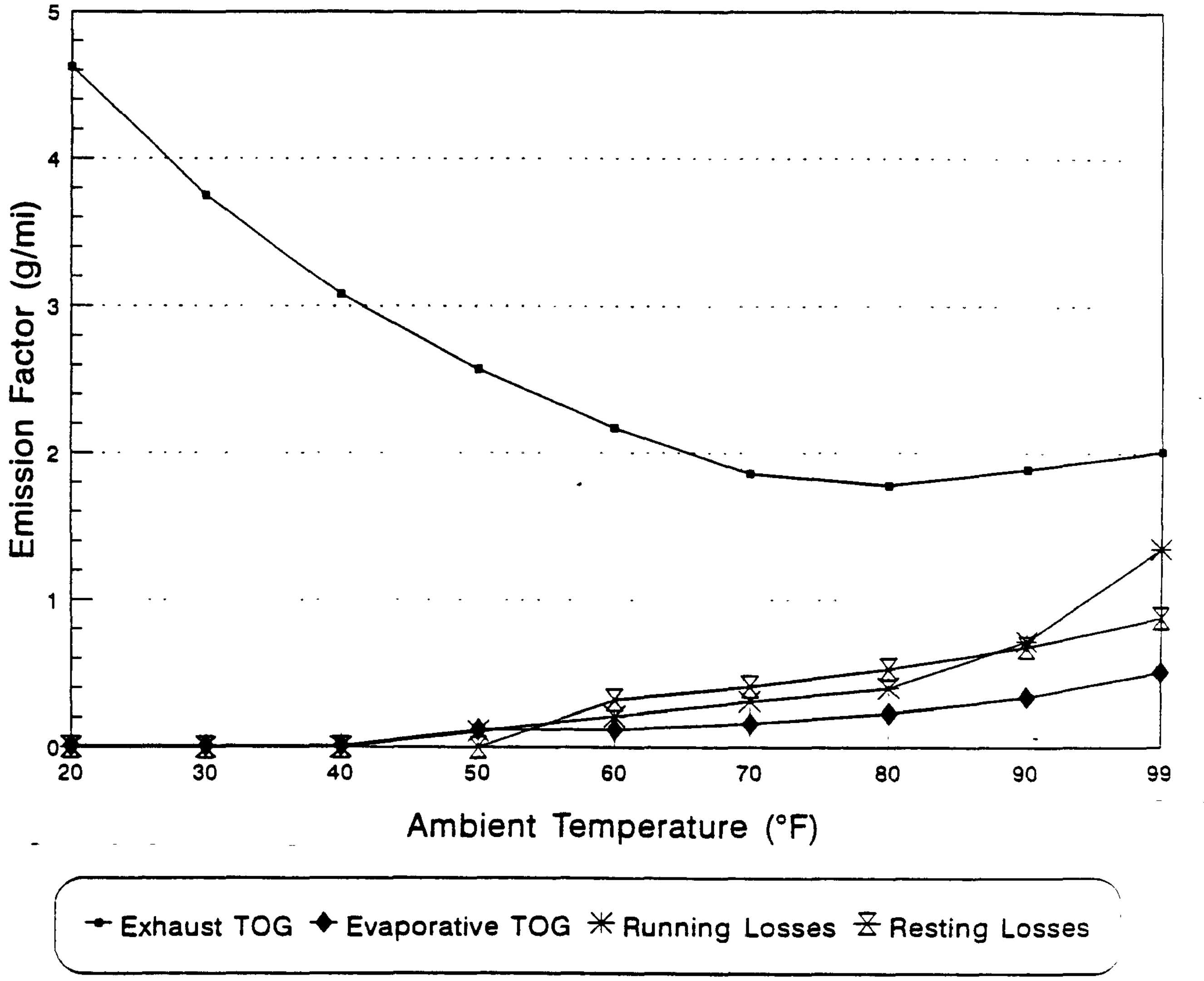


Figure 2-1. 1992 light-duty gasoline vehicle TOG emission rates as a function of temperature.

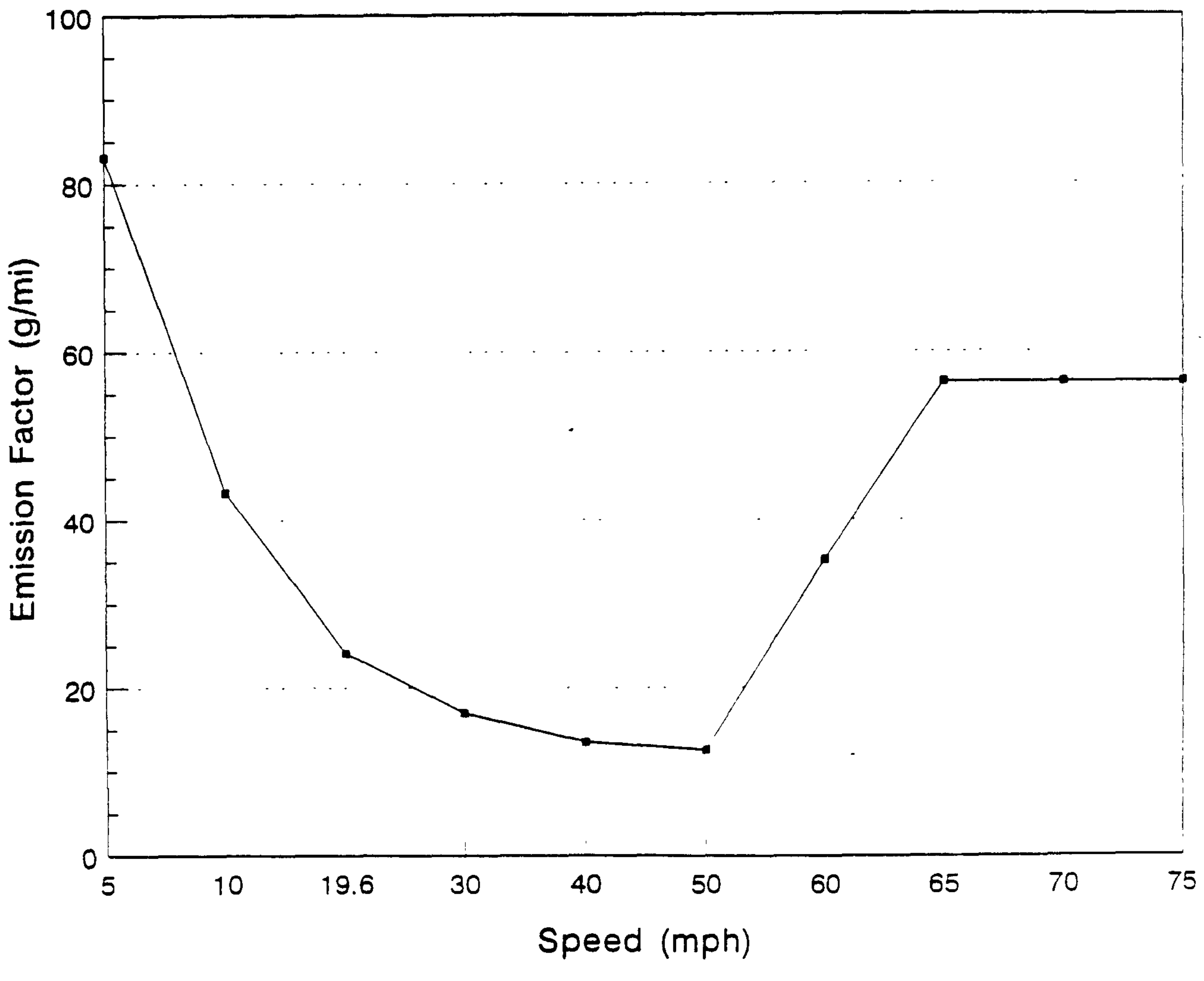


Figure 2-2. 1992 light-duty gasoline vehicle exhaust CO emission rates as a function of speed.

TABLE 2-1. Vehicle class definitions used by the MOBILE model.

Vehicle Class (Abbreviation)	GVW* Specification	Typical Percent of Total VMT
Light-duty gasoline vehicles (LDGV)	Not applicable	62.3
Light-duty gasoline trucks1 (LDGT1)	Less than 6500 lb	17.3
Light-duty gasoline trucks2 (LDGT2)	6500 to 8500 lb	7.7
Heavy-duty gasoline vehicles (HDGV)	More than 8500 lb	3.5
Light-duty diesel vehicles (LDDV)	Not applicable	0.8
Light-duty diesel trucks (LDDT)	Less than 8500 lb	0.2
Heavy-duty diesel vehicles (HDDV)	More than 8500 lb	7.4
Motorcycles (MC)	Not applicable	0.8

*Gross vehicle weight

TABLE 2-2. Commonly used road type designations in emission inventories.

Rural and Urban Interstate
Rural and Urban Other Principal Arterials
Other Freeways and Expressways
Rural and Urban Minor Arterials
Rural and Urban Major Collector
Rural and Urban Minor Collector
Rural and Urban Local

Most transportation models can report VMT by roadway type. However, often both VMT and speed are reported by roadway type averaged over an entire county or transportation modeling region. Improved emissions and air quality calculations can be made if these data are reported on a link-by-link or some other sub-county level, because this allows travel activity to be matched with emission factors which correspond to the speed and temperature conditions under which it occurred. Again, this level of detail is primarily of importance when using gridded photochemical models such as the UAM. The location of emissions and the time of their release strongly affect the ozone production and the development of CO "hot spots."

Spatial Resolution of Mobile Source Emissions

Exhaust and running loss vehicle emissions differ from most other area source categories in that it is generally easier to determine where these emission occur in a region. Spatial distribution of exhaust and running loss emissions can be accomplished using a link-based rather than area-wide surrogate-based gridding procedure such as is used for most area sources. Link-based spatial allocation results in distributing emissions only to those grid cells that contain transportation pathways. In contrast, most evaporative vehicle emissions occur at the location of trip ends, and depend on the number of hours a vehicle is left parked. As a rough approximation, evaporative emissions can be spatially distributed the same as exhaust and running loss emissions, using the gram per mile evaporative rates provided by the EPA's MOBILE model. However, it is more accurate to differentiate between the two emission types, and allocate exhaust and running loss emissions to roadway links and evaporative emissions to the zones where trip ends occur. Within each zone, evaporative emissions can either be assigned to the location of the zone centroid, if the zone is small, or be distributed over the entire zone area using a spatial surrogate such as population. Under most circumstances, the more detailed approach is not necessary unless photochemical modeling inventories are being prepared.

Temporal Resolution of Mobile Source Emissions

Temporal adjustment of the mobile source inventory into monthly, daily, and hourly totals is not a straight-forward process, since transportation models provide little information about the temporal variation of traffic patterns. As noted earlier, transportation models are generally calibrated for use in determining either average or "peak" (e.g., morning or afternoon commute) traffic conditions. Due to the lack of reported information, air quality modelers make assumptions about traffic patterns to estimate the diurnal variation pattern for on-road motor vehicle emissions appropriate for the modeling episode. As a special consideration for weekend emission inventories, note that diurnal variation in weekend driving activity usually differs markedly from weekday patterns. Also, air quality modelers usually assume that the mix of vehicle classes (i.e., problem which arises due to this assumption concerns early morning delivery schedules, which would be expected to result in more activity from heavy duty vehicles in the early morning and a preponderance of light duty vehicles during the am and pm-peak commute hours. In most areas resources do not permit collection of data to explicitly address these issues. However, transportation modelers may have available information on hourly or daily variation in traffic activity that can be used to process the activity estimates from transportation models to arrive at estimates relevant to the time period (e.g., weekday, weekend, hour) of interest in an air quality analysis. Alternatively, data that can be used in allocating daily or peak/off-peak period travel to each hour of the day or for differentiating between weekday and weekend travel patterns may be available from regions that have similar travel patterns to the area under study. Again, this effort need not require development of a transportation model explicitly for weekends or for modeling hourly travel, but instead makes use of data that may be available to transportation modelers for interpreting the outputs from transportation models.

Having described the products from transportation models required by air quality modelers, and the ways in which these products are employed in vehicle emission estimation, the next section will discuss some problems with the information produced by transportation modelers, from an air quality perspective, and implications of these problems for emission estimates.

LIMITATIONS OF TRANSPORTATION MODELS FROM AN AIR QUALITY PERSPECTIVE

Transportation models of varying levels of complexity have been available for use in transportation and air quality studies since the 1950s. Although considerable differences exist between models, they often share a similar framework of assumptions and limitations. The weaknesses of the models from an air quality perspective arise from the model algorithms, the quality of data fed into them, and the way in which a user chooses to exercise them.

Model Algorithms

Model algorithms affect transportation model results throughout the process. Models include different levels of feedback control, different levels of sophistication for the land use and trip generation process, different speed assignment methodologies, etc. A general limitation of travel demand models is that they have been designed for the analysis of regional, corridor, or major facility traffic patterns rather than for analysis of project-level effects, e.g., development of suburban housing tracts or HOV lanes (Ismart, 1991). This limits the use of their outputs to generate accurate estimates of emissions either on a regional basis, where much of the traffic occurs on minor facilities, e.g., urban streets, or on a project level.

All four-step transportation models require the availability of a data set which can be used to characterize the trip generating power of each TAZ. For historical years, this data can be based upon actual knowledge of land uses; relevant information is often collected by local agencies. For future years, either land use models or individual judgement, or more generally a combination of the two, must be relied upon to determine land use patterns. One of the difficulties encountered in land use forecasting is to maintain consistency between land use and the transportation system. This consideration must be included in land use models.

First developed in the 1970s and currently enjoying a resurgence of use, land use models have been used in several U.S. urban areas. Seattle, Los Angeles, San Diego and a number of other urban areas are using such models to forecast land use. These models do create an explicit linkage between accessibility, i.e., the transportation system, and land use. The main components consider accessibility and historical inertia in developing spatial allocations of development. Difficulties in the use of these models stem from the extensive calibration process required and their insensitivities to certain variables in the spatial allocation process. The model being used most extensively in this country is the Disaggregated Residential and Employment Allocation Model (DRAM/EMPAL), developed and supported by Dr. Steven Putman at the University of Pennsylvania, although other models, such as Hammerslag's Spatial Allocation Model, have been developed.

Nevertheless, the interrelationship between socioeconomic and demographic patterns and transportation system changes has not been effectively treated by any model to date (Deakin, 1991). Land use modeling in general is still lacking much of the sophistication needed; no commonly used models treat multi-centered cities well, or capture economic or gender-based differences in drivers, or predict the influence of crime upon land use (Deakin, 1991). Because land use forecasts do not always accurately identify the attractiveness of high growth areas, transportation models often fail to properly assign future vehicle trips to these high growth areas. Inaccuracies in land use forecasts result in inadequate representation of the transportation infrastructure that will be built to service these growing areas, and inaccuracies in the amount of assigned trips. Emissions estimates suffer accordingly. These deficiencies limit a model's ability to correctly forecast the spatial distribution and volume of future travel.

Another problem with some transportation models is that there are conceptual problems inherent in "one-pass" modeling that do not consider feedback effects. As an illustration, changes in travel behavior (e.g., as might result from implementation of roadway tolls) influence congestion and, consequently, travel times; such changes could lead to further behavioral changes that would not be observed unless a model were run until equilibrium conditions were reached. However, though more areas are beginning to use feedback in their models, the sensitivity of models to feedback is still being assessed. A number of different feedback cycles can be implemented in the modeling process. In general, the shorter the cycle, the more common it is to find it used in the modeling process. The most common feedback cycle is the use of vehicle delay to recalculate optimum path. It is the basic nature of the capacity restrained assignment process. Another reasonably common feedback cycle is using travel times from congested traffic assignments to re-estimate modal split. Models which re-estimate trip distribution and/or trip generation based on such criteria are much less common.

Most commercially available software includes equilibrium assignment capabilities. The other feedback cycles discussed simply require the ability to reinput the results of later model stages in a form that can be used by the stage where feedback is desired. The major commercial and public software packages also include this capability. The major capability missing for implementing feedback cycles is a method of testing for equilibrium (program exit criteria). EMME/2 has such a capability for assignment-modal choice feedback, and TRANPLAN is currently implementing similar capabilities.

Speed estimates generated by transportation models are subject to substantial uncertainty depending upon the assumptions built into the modeling exercise. In some cases, for example, speed estimates are derived by assuming that travel occurs on relatively uncongested roadway links. Because speed estimation is often coupled with capacity restraint procedures, assigned speeds may be too high for congested periods, which can significantly underestimate emissions (Cambridge Systematics, 1990). Typically, only one speed estimate is provided for an entire day, or at most peak and off-peak speed assignments are provided, which does not provide as complete a resolution of diurnal variation in vehicle traffic patterns as is required for accurate emission estimation.

Capacity restraint procedures consist of a family of methods to calculate impacts of congestion on vehicle operating speeds. Typically, these methods are implemented as iterative procedures which first assign zone-to-zone traffic interchange volumes based on a set of assumed speeds. These assumed speeds are used to calculate the shortest path between each pair of TAZs in the network model. After all traffic volumes have been assigned to the network, a revised speed and travel time is calculated for each network link based on the relationship between link volume and link capacity. These revised values are used to calculate a new set of paths and subsequently a new traffic assignment. The process continues until program exit criteria are met.

Two basic types of exit criteria are normally used. Iterative and incremental capacity restraint are heuristic procedures with the user defining program exit criteria based on what is considered to be the optimum number of iterations. Equilibrium assignment is an optimizing procedure that attempts to reach travel time equilibrium among alternative routes. This means the models will attempt to iterate until all paths (considering congestion) connecting a pair of zones have the same travel time, or in other words, until there is no advantage to a user switching paths.

An additional problem with model speeds is that they are as much a model input as output, since they are frequently chosen to allocate trips to balance the network. In some circumstances this results in predicted volume to capacity ratios in excess of 1.0 (Applied Management, 1990). A user may sometimes replace model speed assumptions with those derived from Highway Capacity Manual volume to capacity ratios, but such relationships are based upon national average data and do not represent regional speed variations. Finally, models are not designed to predict mileage for non-network coded facilities. Intrazonal travel is an example of this situation. Transportation modelers may typically choose a single region-wide speed to represent such travel.

Model Inputs

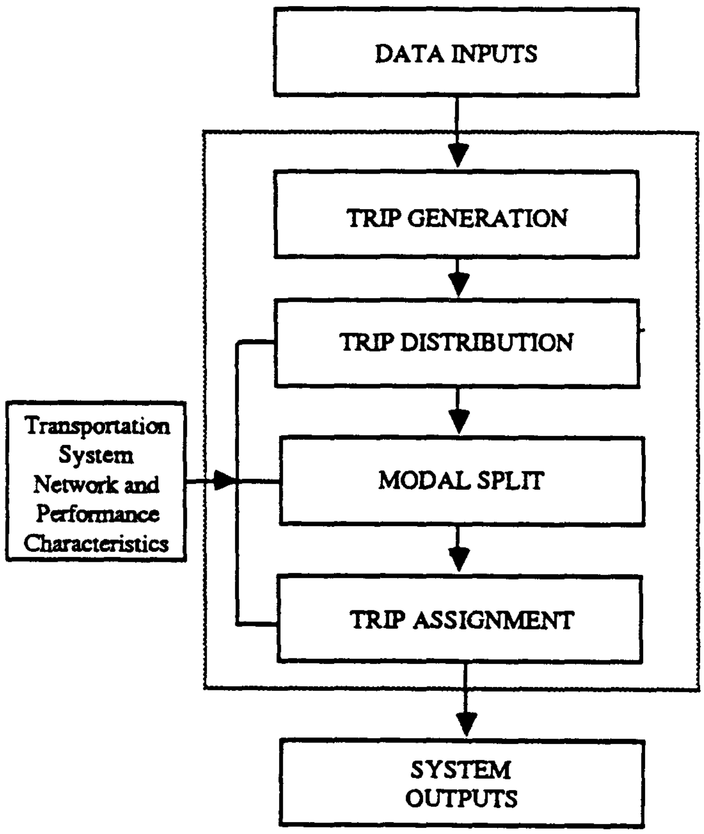
Some of the inputs used by travel demand models are derived from the outputs of other models, i.e., land use or trip generation models. These models have their own associated errors which are often not considered when utilizing them for transportation modeling. Likewise, while each model may have been validated individually against a set of observed data, often the linked series of models are not validated together (Applied Management, 1990). This allows for a compounding of model errors when output from a model that may have appeared correct for the wrong reasons is used as input to the next model.

Some of the difficulties encountered when using transportation model outputs to estimate vehicle emissions arise not from problems with the models, but with the quality and resolution of the data used in the models. Figure 2-3 illustrates the typical four-step modeling process (SAI, 1989). Each step of this process requires inputs from the previous step as well as exogenous model inputs, all of which introduce uncertainty into the model outputs. Table 2-3 summarizes inputs and outputs from a typical four-step travel demand model process.

Several of the inputs listed are obtained from regional origin and destination surveys, which can be out of date. In some areas much of this data was collected during the 1960s. Demographic conditions shift (an example is the proliferation of dual income households), VMT growth rates exceed population growth rates, and "suburbanization" of the work force increases. It is important to insure that forecasted trip activity is based upon realistic travel conditions. This is particularly true with respect to non-work trips.

With older origin and destination surveys, extensive financial resources were sometimes combined with less sophisticated (in retrospect) survey procedures for a collection of large amounts of data. In recent years the financial resources of most areas have not allowed for such extensive surveys, so more sophisticated methods are used to characterize travel behavior in an area, with more reliance based upon taking statistical samples from subsets of a region's population. Uncertainty in this statistical sampling affects travel demand model results, but is generally not reported (Cambridge Systematics, Inc. 1990).

SCHEMATIC	DESCRIPTION



Inventories and forecasts (population, travel demand, land use)

Predicts number of trips produced by, and attracted to, each zone--predicts flows, but not origin or destination (estimates trip frequency)

Predicts production-attractions (P-A) of traffic movements--links trip ends produced by trip generation component (estimates trip length based on P-A)

Predicts percent of traffic movement using each mode option (transit, car, walking, etc.) for each P-A pair (determines mode choice)

Predicts placement of each P-A flow, by mode, on specific travel routes (estimates travel route use by time of day)

Predicts route volumes and travel speeds for each network link, by mode, by morning and afternoon peak and off-peak periods

FIGURE 2-3. Urban four-step transportation forecasting modeling system and typical inputs/outputs.

iii/92004

TABLE 2-3. Summary inputs and outputs for each of the four principal transportation demand analysis steps. (Source: SAI, 1989).

Trip Generation

Inputs: Socioeconomic data, e.g., population, housing (from census tract data), income, employment.

Outputs: Number of trips originating per time period analyzed (typically a day) in a traffic analysis zone (TAZ) (by land use type); trips are broken down by trip type (examples: home-based work, home-based shopping, home-based other, other-based work, other-based other).

Trip Distribution

Inputs: Trip generation data for TAZs and travel times.

Outputs: Distributes the trips generated in individual zones into "production and attraction" pairs, producing trip tables.

Mode Choice

Inputs: Costs, travel times, traveler characteristics, and trip tables from previous step.

Outputs: Determines which travel mode a person chooses to make a trip; assigns motor vehicle trips and forecasts transit ridership; choices vary depending upon model and region (sample choices: driving alone, two-person carpool, three-person carpool, transit/walk, transit/auto). Product is trip tables representing regional travel between zones by trip type and travel mode.

Highway and Transit Trip Assignment

Inputs: Estimates of trips from one TAZ to another, allocated among the different travel modes (i.e., trip tables); data (computer code) of available networks. Other inputs: roadway characteristics (e.g., capacity, travel time from "node to node"), trips per day (for given roadways), road locations, tolls.

Outputs: Trip types are aggregated into time periods (a.m. peak, p.m. peak, off-peak) based upon user-input trip profiles by trip type, which allocate travel activity to peak/off-peak periods. Models then assign each trip to a roadway link(s) and produce daily traffic volumes and speeds, broken down by peak and off-peak periods (i.e., emission "activity" factors); note that traffic engineers are primarily concerned with peak period travel--local model systems/data may not produce hourly or weekend traffic forecasts.

Simplifications Used in Model Execution

User chosen options that affect the quality of transportation model estimates of travel activity include:

Disablement of feedback loops to save time or money;

Application of adjustments to force model predictions to match observed network flows;

Level of aggregation at which comparisons between synthesized and observed base-year parameters are presented;

Model validation procedures (i.e., matching ground counts of vehicles to model predictions);

Level of abstraction used to represent streets and transit routes for computer modeling;

Choice of forecast years.

The effects of most of these actions are relatively simple to explain. Disablement of a feedback loop fundamentally alters the ability of a model to correct itself. Self correction is an abstract concept. While feedback loops do enable some form of equilibration, they are open to criticism due to the tenuousness of the criteria and objective functions used to equilibrate. In other words, "equilibrate" and "correct" cannot be used interchangeably. Such models may or may not be good models of observed behavior.

Likewise, use of large calibration adjustments may destroy the conceptual basis of a model. The validity of calibration adjustments used to improve the match between model predictions and observed base year flows cannot be checked once a model is used for forecasting purposes (Atkins, 1986).

Some of the major calibration adjustments available in travel demand models are discussed next.

The form of trip generation model equations and coefficients is normally model specific and developed on the basis of local surveys.

Trip distribution models and calibration technique depend upon the model form chosen. The most common form is the gravity model. This has two functions which can be calibrated. Friction or accessibility factors (or functions) are used to relate the measured travel time to a destination and the travel time perceived by a driver. The factors are specified as a trip type-specific curve based on travel impedance. Calibration is performed by developing a function(s) that uses existing networks and associated travel times to replicate the distribution of trip lengths observed via survey data. Unfortunately, there may be other influences on trip lengths and spatial distribution of trips besides simple accessibility. These are represented by K-factors which supplement friction factors. K-factors are developed by comparing the survey trip matrices to those generated by a "calibrated" model. Typically, trial and error is used to obtain a better fit between spatial distributions using the analyst's knowledge of the area to determine where and why K-factors must be used. The major problem with K-factors is their longitudinal instability. Replication of existing trip patterns using K-factor adjustments may not properly represent future conditions due to the possible short term nature of the trip pattern influences and aberrations.

Mode choice models are basically similar to trip generation models in terms of calibration. The form and the coefficients are developed based on statistical analysis of local surveys. The most common form is the logit model, which uses the exponential of a mode-specific utility function to predict the proportion of trips served by a particular mode. Models evaluate different statistical fits, whether some input variables can be predicted, and the relative importance of variables in order to provide a workable tool for policy analysis.

Various factoring processes to determine both the percent of trips occurring in a given time period and the directional balance of trips often are applied after mode choice. These are typically based on parallel survey distributions. Also, sometimes correction factors are applied to achieve a better correspondence between total survey trips by purpose and model trips by purpose. This corrects for such problems as underprediction of non-home based trips due to deficiencies in land use data and/or trip generation. One of the most useful numbers for checking the reasonableness of the model available to the transportation analyst is total number of trips by purpose. This provides a check on magnitude of trip generation.

If equilibrium assignment is used, the assignment methodology is self calibrating. The user can control the relative weights of distance and travel time in the composite impedance. However, both link speed and capacity are powerful tools for calibration purposes. Speeds can have a major impact on trip distribution and the typically limited sample of network speeds means that assumptions based on experience, area characteristics, and known facility characteristics must be made for many of the links. Inconsistencies in the size and characteristics of roads along the length of a single link means that, typically, professional judgement is used to estimate a representative capacity for the link.

A separate issue is that the degree of aggregation at which model results are presented for comparison with observed base-year data may mask differences between synthesized and observed data which are important from an emissions perspective, if not necessarily from the perspective of transportation modeling. An example of this occurs when VMT estimates are compared at selected monitoring points, or on a county level. The accuracy of model predictions of speed and volume for the majority of links in the network must be assumed on the basis of this limited comparison. While this type of model validation is satisfactory when travel demand models are exercised to represent the flow of traffic on major facilities, it will not necessarily indicate that the model is performing adequately for minor roadways, which is important from an air quality perspective since travel on minor roadways contributes significantly to regional emissions.

Model validation procedures are generally not standardized. Air quality modelers should be aware that there are substantial uncertainties associated with emissions, air quality, and transportation models. Transportation modeling is referred to as an art rather than as an attempt to mathematically represent various aspects of behavioral science. Air quality officials need to understand the inherent limitations within the transportation data they are using; therefore it is important that the model validation procedure and results be accessible and understandable to the air quality community. Documentation of transportation modeling procedures must be written to be understood by those outside the transportation community.

Another issue arises because a degree of user choice is allowed in selecting the network for transportation models. For example, it is left to the modeler to determine the size and definition of TAZs. Standard practice, in part due to limitations in the size of the calibration data base, is to have small TAZs in urban areas, which allows more detailed treatment of productions and attractions, and large TAZs in outlying areas, where the preponderance of travel of interest to transportation modelers is likely to be on major rather than local roadways. Use of large zones results in much of the traffic being lumped together as intrazonal travel, which the transportation models do not represent well. The degree to which zone definition and sizing can affect model results is significant, but may not be communicated to those interpreting transportation model results.

Related to this is the amount of simplification used to represent a roadway system for a computer model. For example, though important in TCM analysis, high occupancy vehicle (HOV) lanes may not be treated as separate facilities within a model. Ideally, sensitivity exercises would be followed by a modeler in determining both the variation in model results attributable to network definition and to determine as robust, i.e., least likely to have large effects upon model output, network definition as possible. The question of whether network definition should change for forecast years is often not explored either; trending of baseline land use patterns are generally used for forecast years (Deakin, 1991).

A final issue concerns the endpoints used in transportation models. It is not uncommon for air quality modelers to have to interpolate between sets of model predictions to develop estimates for the years of concern from an air quality perspective. For example, regional transportation agencies forecast roadway use for different time periods than the planning horizons used by air quality planners. Often, air quality planners require data over shorter horizons, such as for three to five year intervals; transportation modelers may focus on ten to twenty year projections that do not overlap air quality planning milestones. Interpolation schemes for calculating intermediate transportation planning estimates may not accurately reflect those future transportation conditions.

SUMMARY OF CONCERNS AND THEIR RELATIONSHIP TO TRIP, VMT, AND SPEED ESTIMATION

As detailed above, there are discrepancies between the needs of air quality models and the ability of transportation models to predict travel activity. These are related to the algorithms used in a typical four-step travel demand modeling procedure, the quality of input data used in the models, and the user choices which affect how the models are applied. Table 2-4 summarizes the problems discussed, their effects upon both transportation and emission estimates, and a general estimate of the potential significance of each issue. Note that estimates of significance depend greatly upon both the characteristics of the region studied as well as the goals of an air quality analysis. The reader should keep in mind that uncertainties are found in the processes used for emissions and air quality modeling as well as in transportation modeling.

TABLE 2-4. Potential issues of concern in using transportation models for air quality analysis.

Issue	Transportation Parameters Affected	Emission Parms Affected	Bias Direction	Potential Significance*
Accuracy of land use forecasts, or forecasts developed in response to policy decisions	Spatial allocation; congestion levels; VMT, trips, speed	Spatial and speed distribution, VMT, trips	?	M
Roadway capacity restraints and average daily traffic volumes used to estimate speed	Overestimates of speed under congested conditions	Speeds too high at peak travel periods, too low for off-peak	Probably underestimate emissions	H
Lack of feedback among the four steps of the modeling process	Inconsistent volumes and speed; travel behavior not allowed to change with congestion	VMT, trips, and speed	?	M
Intrazonal travel modeled with less detail than link-based travel	No detail on speed; volumes underestimated; limited spatial resolution	VMT, trips, and speed	Underestimates emissions	M
No hourly traffic estimates	Only daily or peak-period traffic estimates provided	Temporal disaggregation of emissions accomplished through post-processing	Probably underestimates emissions	L
Land use and travel forecasts are generally for long time increments	Year-to-year traffic variation not treated	Emissions may be needed for much shorter time increments	?	M
Model validation procedures and goals are not standardized	No uncertainty estimate for transportation results	No uncertainty estimate for emissions	?	L

Continued

TABLE 2-4. Concluded

Issue	Transportation Parameters Affected	Emission Parms Affected	Bias Direction	Potential Significance*
Range of variability in model inputs (e.g., speeds, network definition) is not quantified	No uncertainty estimate for transportation results	No uncertainty estimate for emissions	?	L
No seasonal or weekday/weekend effects	Transportation results only available as annual averages	Emissions are often required for specific episodes	?	L
Outdated survey data used	Introduces extrapolation errors; recent changes in travel behavior not treated	More potential errors in VMT, trips, and speed	?	H
Use of calibration adjustments to allow models to match historical observed travel patterns	May invalidate model forecasts	Could introduce artificial-ity into resulting emissions	?	M
Modeled region does not correspond to air quality analysis region	Activity estimates are missing or have little detail in outlying areas	Vehicle activity levels must be extrapolated or adjusted for outlying areas	Underestimates emissions on edges of modeling region	M

* H = high, M = medium, L = low

3 HOW TO DIAGNOSE MODELING DIFFICULTIES

In the previous chapter, potential weaknesses in transportation models from an emissions perspective were discussed. Where possible, the resulting effects of these weaknesses on estimates of trips, VMT, and speeds input to emission models were indicated. This information was summarized in Table 2-4. This chapter will assist the reader in developing a list of questions which should be discussed between air quality and transportation analysts.

KEY QUESTIONS TO ASK YOUR TRANSPORTATION MODELING AGENCY

The development of vehicle emission inventories suitable for air quality modeling purposes is a cooperative effort between air quality and transportation agencies. In order for the effort to succeed, this cooperation must extend throughout the transportation and air quality modeling process. In the following section we will provide a series of questions which should be discussed between air quality and transportation modelers. It is important that transportation modelers understand what air quality personnel require in transportation modeling outputs and that air quality staff understand the limitations of transportation models from an air quality analysis perspective.

Although ideally these discussions would take place as a transportation model is developed for an area, the reality is that many areas already have transportation models in place. Hence, these questions serve as tools air quality modelers can use to develop a deeper understanding of an existing transportation model, or as issues to be discussed during the update of a preexisting transportation model.

For example, an air quality modeler may intend to use the transportation modeling outputs to develop a seasonal emission inventory. In many regions, there are significant seasonal variations in traffic patterns. An agricultural region would experience increased commercial traffic (i.e., heavy-duty diesels) associated with the transport of crops during harvest times. Areas near recreational attractions, such as skiing, would have increased automobile traffic during the winter months. There might be particular events specific to the year an air quality modeler is interested in, such as freeway repair, which would have significant short-term impacts on traffic patterns. At the same time, a transportation modeler needs to communicate to air quality personnel the necessary assumptions involved with transportation models, and features of the models which might be viewed as limitations from an air quality perspective. For example, transportation models are not designed for the detailed representation of intrazonal traffic, and specific assumptions are required of a modeler in order to provide VMT and speed estimates for this type of travel.

The questions discussed below are loosely grouped by the typical four steps of transportation modeling which they concern. These are trip generation, trip distribution, mode choice, and highway assignment. The characteristics of these four steps have been discussed in general terms in Section 2. More detail will be given on each stage in the following pages in order to show the context of these questions. Some of the suggested questions affect more than one of the transportation modeling stages. In this case, we discuss the question at the earliest stage of the transportation modeling process.

TRIP GENERATION

Trip generation is where socio-economic land use data and projections are used to estimate the number of productions (trip origins) and attractions (trip destinations) associated with each TAZ. As discussed in Section 2, some of the limitations of transportation models, from an emissions perspective, arise from the land use data and projections used at this stage of the modeling process. A transportation modeler must use these data, which provide such information as the numbers of homes, shopping centers, businesses, or distribution centers in a TAZ, along with estimates of the numbers of trips produced and attracted by each of these land uses, to calculate total trip productions and attractions for each TAZ.

There are several areas of discussion for transportation and air quality modelers at this stage of the process. These concern the following issues:

Land use and model calibration data;

Generation of productions and attractions in TAZs;

Trip types;

Structure of traffic analysis zones.

The significance of these issues varies depending upon the characteristics of the area under study as well as the goal of the study. All have the potential to be very significant, particularly in studies evaluating the comparative impacts of different emissions control strategies, or in studies using photochemical modeling tools.

Land Use and Model Calibration Data

Air quality personnel should determine the age and source of the land use and model calibration data used. Although the distribution of land uses responsible for most of the home-based-work (HBW) trips that are the main interest of transportation modelers may be relatively unchanged from when the data were gathered, shifts from urban to suburban populations or in the income levels in zones can have significant effects on the number of trips produced and attracted by each zone and may not be represented in older land use data. As mentioned in Chapter 1, some regional models are based on outdated survey data. Resources are frequently not sufficient to permit updating of these surveys with their original level of detail. Air quality modelers need to be aware of the limitations of the surveys that will be used to develop a transportation model, and the methods chosen to update them. Such understanding can indicate where further refinement of the data is required.

Land use forecasts to future years are a source of uncertainty in transportation modeling. In the past the same spatial distribution of productions and attractions was sometimes used for both a base and future year, and the number scaled based upon a set of assumptions. In other cases policy decisions may have unreasonably influenced land use projections. The development of land use forecasts should be an issue of concern for air quality modelers, because the spatial distribution of emissions can significantly affect production of ozone and carbon monoxide. Assumptions about future density limits and zoning are important, especially in evaluating denser, transit-rich development alternatives aimed at improving air quality. The methods used to predict the future land use or development distributions need to be discussed between air quality and transportation modelers to ensure that they are appropriate for emissions modeling. Alternative development scenarios should be considered for possible regional plans to reduce emissions.

Generation of Productions and Attractions in TAZs

Finally, the methodology used to estimate the number of productions and attractions in each TAZ should be discussed among air quality and transportation modelers. This step of the process results in a forecast, different between base and future years, of the number of productions and attractions in each TAZ. Different estimation methods may result in different strengths and weaknesses in the resulting modeling results. Some methods that have been used for this include optimal adaption to census data, home interviews, measurements of distances, traffic censuses, etc. (Hamerslag, 1980). The air quality modeler should be aware of what parameters drive the trip generation models (e.g., household or employment characteristics), and whether an attempt is made in the models to relate travel demand to the transportation system capacity.

Trip Types

The socio-economic characteristics of a TAZ (e.g., number of households or employees) will determine both the number and the types of trips which it produces and attracts. Although a transportation modeler can choose to explicitly represent any set of trips with a common purpose within the model, commonly used trip types are: home-based work, home-based school, home-based shopping, home-based social/recreational, home-based other, non-home-based trips, through trips (i.e., which neither begin nor end within the modeling region), and trips which originate outside the modeling region but end within it and vice-versa.

The types of trips a transportation modeler explicitly treats are of importance to the air quality modeler. For example, there is generally little survey data available on commercial travel, i.e., heavy duty diesels, yet this is the source of a significant amount of emissions. Transportation modelers may arrive at VMT, trip, and speed estimates for this component of regional travel through postprocessing steps, or by setting it up as an explicit trip type in the model. Either method will require a series of assumptions as to volume and distribution of commercial travel. These should be discussed, and the method chosen to treat commercial traffic and any other trip type not directly modeled understood by the air quality modeler.

Transportation models are best at treating home based work trips, in part because a major source of information on these trips is available for all regions from data collected by the U.S. Census. Frequently trips for shopping or recreational purposes are treated as a general category, such as home-based other. The air quality modeler should determine exactly what trip types are contained in these general categories, and work with the transportation modeler to ensure that all trip types are included in the model. The level of detail at which specific trip types should be treated depends to a large extent on its anticipated contribution to regional emissions. To return to our example of commercial travel, heavy duty trucks are a significant source of NO_x emissions, particularly in future years, yet no widely used models of goods movement processes are available. Given the available data their treatment in transportation modeling should be as detailed as possible and the limitations in the model predictions for this vehicle class understood by the air quality modeler.

Structure of Traffic Analysis Zones

The air quality and transportation modeler should discuss the methodology followed in defining TAZs. In particular, the region modeled with the transportation model should match the region of interest for air quality analysis. Outlying areas can serve as important sources of emissions which lead to exceedances of air quality standards. These outlying areas may either be modeled with less detail or not modeled at all by transportation models even though they are significant from an air quality perspective. Similarly, it is often not enough to include only a nonattainment area in the transportation model, since the regions that are modeled in air quality models are usually larger than the nonattainment area in order to include pollutant emissions that can be transported (by wind) into the nonattainment area during the period of time modeled (typically one or more days). Therefore, when first setting up or when updating a transportation model, efforts should be made to ensure that it will cover a reasonable amount of the area contributing to the degradation of air quality in a nonattainment area. In the case of preexisting models that fall short of this goal, transportation modelers may be able to suggest alternate sources of information on travel activity that can be used to develop emission estimates for the outlying areas.

The level of detail used in modeling a region and the variation in this level of detail as the network is defined for the entire region of interest should also be discussed. Since the air quality perspective as to what constitutes important travel activity is not always the same as the transportation modeling perspective, this communication will help to ensure that travel activity that contributes disproportionately to air quality problems is adequately modeled.

The next section will discuss questions which should be raised by an air quality modeler concerning aspects of the trip distribution portion of the transportation modeling process.

TRIP DISTRIBUTION

Trip distribution takes the number of productions and attractions associated with each TAZ, as determined in the trip generation stage of this process, and predicts how traffic will be distributed between TAZs. Key parameters at this stage of the process are friction factors, travel time, and K-factors, which indicate the relative likelihood of travel involving different levels of time, distance, or cost occurring between TAZs.

Two key areas of discussion for transportation and air quality modelers occur at this stage of the process. The first is the development and use of friction factors and K-factors for the region. The second concerns representation of intrazonal travel.

Development of Friction Factors and K-Factors

Friction factors (often functions) are generally developed from local survey data for each trip type in the model. People's willingness to invest time or money in a trip depends largely on the reason for the travel. For example, one would likely travel farther in order to reach one's place of employment than one would travel to buy groceries. K-factors, on the other hand, perturb the trip distribution that would otherwise result. Take the case of Chicago, for example. There a central business district is surrounded on the west and south sides by low-income areas. Further west are affluent suburbs. K-factors that diminish the effect of the friction factors are needed to bring the suburban traffic into the central business district. At this point, the air quality modeler should discuss with the transportation modeler the methodology and assumptions used to determine friction and K-factors, paying particular attention to assumptions used to determine differences in travel behavior by trip types. The error range of the friction factors and limitations which may result from local surveys used to develop them, or from the representativeness of the sample size and sampling methods, should be understood by the air quality modeler. This can help to determine whether old surveys should be updated with spot sampling techniques, or whether further survey information is required. K-factors, which are developed to adjust travel behavior to more closely resemble current conditions, may not be appropriate when forecasting travel activity. Hence, the effect of such factors on travel activity estimates should be understood to determine if forecast travel activity is unduly affected by the application of K-factors.

Intrazonal Travel

It is during the trip distribution stage of transportation modeling that the amount of intrazonal travel is determined. At this stage, only the number of intrazonal trips in each TAZ is estimated. The transportation modeler must develop a set of assumptions to assign speed and VMT to these trips and to determine the fraction which is non-vehicle trips (e.g., walk/bike trips). Since this component of regional travel is important from an emissions rather than from a transportation modeling perspective, it is important that the air quality modeler discuss with the transportation modeler how intrazonal travel can be treated. Assumptions applied to this type of travel should be stated. Additional insight into intrazonal travel might be obtained by examining the procedures used to estimate travel on local facilities for the Federal Highway Administration's Highway Performance Monitoring System (HPMS). As stated in the EPA's *Interim Guidance for the Preparation of Mobile Source Emission Inventories* (Lorang, 1991), though local road VMT estimates are generally not based on the statistical procedures used for other facility types, HPMS reports do contain VMT estimates for local roads.

MODE CHOICE

Mode choice is an optional stage of the transportation modeling process; however, some form of transit estimation is done in all areas. Mode choice models are used to determine the proportion of trips to be modeled as public transit, which includes such travel modes as buses or light rail systems. A separate computer simulation of the roadway network is generally developed for public transit, and is in some ways simpler than that used for other travel modes. For example, transportation models usually assume uniform spacing between bus arrivals. (An exception is the VTS Interactive Planning System (VIPS), developed by VTS Systems Corporation of Sweden, which uses a probabilistic estimation of bus arrivals.) Few models treat multi-path public transit. However, public transit models are generally based upon very explicit route information. Mode choice is of particular importance from an air quality perspective if transportation control measures or improved public transit systems are to be evaluated as tools for improving air quality.

Areas of discussion at this stage of the transportation modeling are:

> Treatment of public transit, i.e., whether it should be modeled separately from other travel modes and what types of public transit scenarios should be evaluated;
>
> Determination of public transit travel, i.e., how the proportion of vehicle trips diverted to public transit is determined or how vehicle trips to central transit facilities, such as park-and-ride lots, are treated;
>
> Urban bus VMT.

Treatment of Public Transit

The decisions as to whether public transit should be modeled separately from other travel and what types of transit scenarios should be evaluated depend upon the overall purpose of the air quality modeling. If control measures that include public transit measures are being evaluated, public transit should generally be modeled separately from other travel. Specific scenarios relating to public transit issues that an air quality modeler intends to model should be communicated to the transportation modeler, since scenario definition will affect assumptions made at this stage of the modeling process. An example is an air quality improvement measure meant to increase the cost of using a personal automobile for commuting to work, in order to encourage drivers to switch to public transit.

Since cost is an important factor in an individual's decision to use public transit systems, or to choose one public transit option over another, air quality modelers should ask how cost is included in the public transit portion of the transportation modeling process. They should also be aware of how income data was incorporated into the original land use data, since income level correlates with public transit use, and how accessibility to public transit is addressed.

Determination of Public Transit Travel

When mode choice models are used, air quality modelers need to be aware of what assumptions were used to assign riders to the public transit network. The breakdown of public transit travel into components such as buses or light-rail systems should be understood. Survey data are often used to establish the amount of public transit travel.

Spot surveys are difficult to develop for public transit use, since public transit represents a small portion of overall travel. As a result, mode choice models are often the most difficult to calibrate. Air quality modelers need to know the limitations and error ranges associated with public transit surveys, in order to correctly interpret the results of modeling exercises.

Air quality and transportation modelers should discuss how trips to public transit facilities such as park and ride lots or subway stations are treated. Although these trips may not be important from a transportation perspective, and are often intrazonal trips, they may still be a significant source of vehicle emissions. This is because emissions from vehicles that have not "warmed up" are higher than emissions from vehicles that have been in operation for a few minutes, i.e., although the VMT associated with trips to public transit centers may be small, the emission rates for this type of travel are often much higher than vehicle emission rates during standard commutes. Another related topic of discussion is whether any attempt is made to model increased vehicle usage from people driving passengers to public transit centers. Historically, within transportation models the transit network has not been integrated with the overall roadway network, which increases the difficulty of modeling all travel effects arising from use of public transit. One approach to improving transportation models is to maintain correspondence between the two networks.

Urban Bus VMT

Air quality modelers involved in TCM analysis should know the proportion of VMT due to urban bus travel. The emission rates of buses are significantly higher than those of passenger cars, and this characteristic should be modeled in producing emission inventories. This is important when evaluating the effects of TCMs which propose increased transit use. Urban buses are also likely to be targeted for alternative fuel use, since they are frequently fueled from a central fleet location. In such situations, an air quality modeler needs to know the amount and location of travel associated with these vehicles. Although transportation models may not readily lend themselves to tracking urban bus travel, discussion of these needs with the transportation modeler and understanding of the assumptions followed in modeling urban bus travel will certainly improve representation of these emissions. Note that integration of the highway and transit networks is one tool available in transportation modeling to improve estimates of transit use. This technique is demonstrated in Section 4.

The next section discusses questions which should be posed by an air quality modeler which concern the trip assignment stage of the transportation modeling process.

TRIP ASSIGNMENT

Trip assignment is where the actual routes taken for trips between zones are determined, generally based upon the path which has the shortest travel time (alternatively distance or cost can be used). There are various methods available for this step of the process. One of the most common, currently, is for the model to try different routings of trips between origin and destination pairs until a user-specified equilibrium is attained. This is an iterative approach which recalculates trip assignments based upon the systemwide congestion on links. Equilibrium in this case is defined as the point at which there is no alternative way to assign a trip without producing a net increase in system-wide travel time.

Link distance and estimated speeds are inputs to this process. Output speeds are then calculated for each link, often based on volume to capacity relationships. Different levels of feedback allow a model to achieve some stability in the final speed estimates. An heuristic approach can also be followed in modeling network speeds, where the user defines program exit criteria based on what is considered to be the optimum number of iterations.

Questions which should be asked of the transportation modeler at this stage concern:

- Choice of travel route;
- Choice of initial speeds;
- Assignment methodology;
- Use of feedback;
- Temporal variation in traffic.

Choice of Travel Route

Air quality modelers should ascertain the criteria for assigning the path taken between zones. They should understand the conversion of cost factors, such as bridge tolls, to distance or time increments on the affected link within the model. If certain types of travel are restricted on specific links in the region, or if some links are more likely to draw a specific type of travel even though they may not represent the shortest distance between points, the way in which this is represented in the model, or if it is represented, should be discussed. Examples of such situations are highways on which heavy-duty truck travel is prohibited, or specific highways that draw a disproportionate amount of the heavy-duty truck travel in a region. Diversion of certain types of travel, such as commercial, to specific routes may affect the vehicle emission factors that should be used to calculate emissions for these links.

Choice of Initial Speeds

Initial estimates of speeds for each link in the highway and transit networks may be taken from actual surveys or be assigned on the basis of the road (i.e., facility) and area type of each link. The air quality modeler should ask how initial speeds were determined, since these can affect both how trips are distributed in a region and the final speed estimates produced by the model. Possible approaches include starting the model with congested speeds or speeds representative of the time of day modeled (e.g., off peak, morning peak), or starting the model with freeflow speeds so that the model is allowed to develop the congested speeds. Further research needs to be conducted to resolve this question. Lack of local survey information on speeds may force reliance upon standard reference manuals, such as the *Highway Capacity Manual* (Transportation Research Board, 1985) to assign initial speeds based on area and roadway type. Error in model outputs due to the choice of initial speed can be bracketed by the transportation modeler, as discussed in Section 4, which would help in determining the importance of the initial speed estimates.

Assignment Methodology

The air quality modeler should be aware of what methodology was used in the trip assignment model, and how a specific method may affect model output compared to a different method. The weaknesses and strengths of the methodology chosen, in terms of the spatial distribution of trips and VMT, and speed estimates, should be known. One typical assignment method used is free-flow, whereby all selected trips are located on the minimum paths (based on time, distance, cost, or user impedances) of the network. Another method is restraint loading, which is similar except that the network parameter time is adjusted link by link according to a capacity restraint formula. Still another method is incremental loading, where for each iteration a user-specified percentage of selected trips is loaded on the minimum paths determined during path building (the network parameter, time, is adjusted link by link according to a capacity restraint formula). The air quality modeler should discuss with the transportation modeler the reasons for the methodological choice. Important assumptions are made at this stage of the modeling process which will have significant effects upon the final VMT and speed inputs to the emissions models, as well as the final spatial distribution of the vehicle emissions. For example, curves which are used to relate traffic delay and congestion can either represent relative or absolute delays, a distinction which can affect how well model treatment of traffic delay matches real world conditions.

Use of Feedback

Transportation models can use some type of feedback to refine their initial estimates of VMT, trips, and speed in an attempt to reflect real-world conditions. The speeds produced by the trip assignment model may significantly affect the travel times between specific zones, making it more likely that travel will be routed to another zone than had been predicted in the first pass through the trip distribution stage. Rerunning portions of the model with these new predicted speeds can, in some cases, improve the model predictions when coupled with knowledge of how congestion impacts destination choice. Some models will even go back to the original trip generation stage, using model predictions to modify the land use data. More areas are considering using feedback in their transportation models, in part in response to a lawsuit filed by the Sierra Club and Citizens for a Better Environment against the San Francisco Bay Area's Metropolitan Transportation Commission (MTC) and associated parties challenging some elements of the Bay Area's 1982 State Implementation Plan. The MTC's MTCFCAST models have feedback capabilities that, in the past, were rarely employed in practice by MTC staff. This practice was one source of criticism of MTC in that lawsuit. An air quality modeler should be aware of the amount of feedback, if any, employed in running the model, and what criteria were used to determine when the final set of model outputs had been reached.

Temporal Variation in Traffic

Air quality modelers often require hourly emission estimates. The usual practice is to process the daily or peak and offpeak period estimates of travel activity available from transportation models to arrive at hourly estimates. Transportation modelers typically break daily average traffic estimates into estimates for peak and offpeak periods between the mode choice and trip assignment steps in the typical four-step model. Working together, transportation and air quality modelers can decide the level of breakdown required given the anticipated use of the transportation model outputs as well as the data available. For example, modeling travel activity separately for off peak, morning, midday, and afternoon peak periods is in most cases sufficient for developing defensible estimates of hourly vehicle emission inventories. Alternatively, daily travel activity estimates from a transportation model can be disaggregated into hourly activity estimates as a postprocessing step to the transportation modeling. Through analysis of regional survey data, transportation modelers are uniquely qualified to provide advice on developing hourly activity profiles specific to the area of study.

Once the number of time periods to be modeled is decided, the temporal variation in zonal characteristics must be determined. An air quality modeler should determine if regional factors will be used to allocate traffic to specific time periods, or if subregional or even zonal factors will be used. TAZs within a region will not be active at a uniform level for each time period modeled. As an extreme example, zones with a high concentration of offices might be almost deserted during off-peak hours, whereas zones with recreational attractions could be at their most active during these times.

The same issues must be considered when transportation outputs are to be used to model weekend episodes. One would expect less temporal variation in traffic patterns on weekends. However, the number of productions and attractions associated with each TAZ could be different than that calculated for weekdays. Business districts might be relatively inactive, whereas recreational areas would be the primary source of attractions, and activity might be more uniform throughout the day. Although it is uncommon to model weekend travel with transportation models, since most areas lack sufficient data, adjustments for estimating weekend travel activity from transportation model outputs should be discussed when air quality episodes include weekends.

SUMMARY OF KEY QUESTIONS

The key issues of discussion between air quality and transportation modelers are summarized in Table 3-1, grouped by the four transportation modeling steps. Current practice as well as suggested improvements are discussed when possible.

At this time it is difficult to estimate the potential significance of all of these issues, especially since the significance will vary depending upon the region studied and the purpose of the study. Many air quality analyses compare emissions reduction strategies which are very similar in terms of magnitude of emissions reduced, but which target emission sources with different photochemical reactivity or which occur at different times of day. The resulting impact of such strategies on air quality is nonlinear in nature. Studies have found that simply shifting the time of occurrence of emissions by an hour will have a significant effect upon the buildup of pollutants in an urban area (Ireson et al., 1987). Rigorous quantification of the significance and the cost effectiveness of addressing the issues listed here is outside the scope of this study, but may be addressed in subsequent studies carried out by the EPA. In general terms, temporal variation, the accuracy of land use data and projections, inclusion of intrazonal travel, methods used for predicting speeds, and the use of feedback within the model are most significant among the issues listed in Table 3-1.

TABLE 3-1a. Summary of key questions: trip generation.

Area of Discussion	Question	Potential Effects and Solutions
Temporal Variation	What are the time periods/days of week being modeled?	Current practice is generally to model weekday travel for a peak and off-peak period. Results are reported as daily totals. Air quality (AQ) modelers need hourly emissions estimates for both weekday and weekend travel. Division of modeling periods into AM peak, PM peak, off-peak and between peak periods to better characterize different travel demand characteristics. Using transportation models for weekend episodes should also be discussed.
Land Use Data	What is the vintage of the land use data being used by the transportation modeler?	Changes in urban and suburban populations can have significant effects on spatial distribution of emissions. Older surveys may not reflect population distribution changes for the periods of interest to air quality modelers.
Trip Types	What types of trips are or are not normally treated by the transportation modeler? How are estimates of the non-treated trips' activity developed?	Transportation models are most widely used to characterize home-based work trips. Non-work trips are often placed in a "home-based other" category. Lack of survey data for commercial traffic has necessitated extensive assumption-making when determining VMT, trip, and speed estimates for this trip type. Different modelers may have different methods of handling this problem. The contribution of commercial travel (heavy duty trucks) to emissions is significant. Air quality modelers must be aware of the limitations of the transportation models in handling this trip type.
Determination of Productions and Attractions	What methodology is being used by the transportation modeler to generate productions and attractions in TAZs?	Different trip generation methodologies may result in varying strengths and weaknesses in transportation modeling results.

TABLE 3-1b. Trip distribution.

Area of Discussion	Question	Potential Effects and Solutions
Development of Friction and K-factors	What is the methodology used to determine friction and K-factors?	AQ modelers need to discuss with transportation modelers the assumptions used to determine differences in travel behavior by trip types. The error range of these assumptions should be fully understood by AQ modelers. If AQ modeling is to be conducted for a particular season or episode, conditions which could affect the decision to travel should be considered in friction and K-factor development.
Intrazonal Travel	What assumptions does the transportation modeler make when determining speed and VMT for these trips?	Only the **number** of intrazonal trips is calculated by the transportation model. The transportation modeler must make assumptions to assign VMT and speeds, and to determine the fraction of non-vehicle trips. VMT and speeds are much more important from an emissions perspective; AQ modelers should discuss how intrazonal travel will be treated with the transportation modeler before the process begins. Comparisons of intrazonal travel estimates and assumptions with procedures used for the HPMS.

TABLE 3-1c. Mode choice.

Area of Discussion	Question	Potential Effects and Solutions
Treatment of Transit	What scenarios does the transportation modeler intend to model? How does cost figure into these scenarios?	Which transit scenarios are to be modeled depends heavily upon the overall purpose of the AQ modeling. EXAMPLE: If control measures (e.g. transit) are to be modeled, transit should be treated separately but not in isolation from other modes. Income level correlates with transit use; AQ modelers should understand how this information is incorporated into the transportation model.
Determination of Transit Travel	What assumptions are used to assign riders to the transit network? How are trips to transit facilities (e.g. park and ride lots) treated by the transportation model?	AQ modelers need to understand how transit travel is broken down into components (e.g. ridesharing, buses). If survey data are being used, AQ personnel should understand the limitations and error ranges associated with these surveys. Trips to transit centers, though not of great importance from a transportation modeling perspective, are very important from an emissions perspective. AQ and transportation modelers need to discuss methods of handling this.
Urban Bus VMT	What is the amount and location of travel associated with these vehicles?	Emissions rates of these vehicles tend to be much higher than those of light-duty vehicles. AQ modelers need to understand the assumptions made in modeling this mode to better represent its contribution to emissions.
Seasonal or Episodic Effects	How can transportation models be used to model a specific season or episode?	Transportation models are typically developed for annual average applications; however, more specific time periods could be modeled. Discussions between AQ and transportation modelers concerning the characteristics of these seasons/episodes are necessary if they are to be modeled.

TABLE 3-1d. Trip assignment.

Area of Discussion	Question	Potential Effects and Solutions
Choice of Travel Route	What criteria are used for determining the minimum path between zones? How are cost factors converted to distance or time?	Certain types of travel may be restricted from using some routes within a network. Also, specific links may be more likely to draw certain types of travel, even though use of a particular link may not represent the shortest distance. Diversion of certain types of travel (e.g. heavy-duty truck traffic) may affect the vehicle emission factors used to estimate emissions on these links.
Choice of Initial Speeds	How are initial speeds determined?	Speed estimates for links may be taken from actual survey data or be assigned on the basis of facility (e.g., arterial) and area type (e.g., urban) of the link. AQ modelers should ask how these estimates are made since they can affect trip distribution within the region and final speed estimates produced by the model. Lack of local data may result in the transportation modeler relying upon reference manuals for default values. AQ modelers need to understand how this may limit speed estimates and the error ranges of these estimates.
Assignment Methodologies	What methodology was used in the trip assignment model? How can different methodologies affect model output?	Different methodologies used in trip assignment have varying strengths and weaknesses, in terms of trip distribution, speeds, and VMT. AQ modelers should discuss with transportation modelers the reasons for choosing one method over another. AQ modelers should also discuss any assumptions that may have been made by the transportation modeler at this phase of the process.

continued

TABLE 3-1d. Concluded.

Area of Discussion	Question	Potential Effects and Solutions
Use of Feedback	What are the types and amounts of feedback being used by the transportation modeler? How are VMT and speeds calibrated with the actual case, i.e., how well does the model predict?	AQ modelers need to understand the types of feedback being used in the transportation model, and the effects of this feedback on model outputs. AQ modelers should also understand the criteria used to determine when the "final" set of model outputs have been reached (equilibrium is an example of a common criteria).

4 AIR AGENCY STAFF GUIDANCE: SUGGESTED PROCEDURES FOR IMPROVING THE LINK BETWEEN TRANSPORTATION AND AIR QUALITY MODELS

OVERVIEW

This chapter discusses a range of procedures which could be used to improve the linkage between transportation and air quality models. The ease with which these suggested improvements can be applied using current transportation modeling systems is discussed below. Sample model results for four of these options, developed using a prototypical model, are provided and discussed.

Future EPA studies may be carried out to quantify the effectiveness of these suggestions in terms of cost and impact. The complexity of transportation and air quality modeling techniques make it difficult to estimate effectiveness without implementing these suggestions with actual transportation models for a variety of urban areas and evaluating their relative impacts for different scenarios. Some of these suggestions are simple and inexpensive to implement and result in travel activity estimates which are better matched to the needs of air quality modelers (this is the case for some of the postprocessing techniques that are described), and therefore should more readily be considered when using transportation models in air quality analyses. Obviously, some of the techniques, such as those involving detailed treatment of transit, are useful only in a few situations, such as in the evaluation of transportation control measures.

SUGGESTED PROCEDURES FOR IMPROVING TRANSPORTATION MODELING

The suggested procedures for improving the link between transportation and air quality models have been grouped into five general classes,(the procedures are summarized in Table 4-1):

1. General Improvement to Travel Demand Forecasting. This includes procedures that use available tools and information, such as reestimation of origin and destination information using observed traffic volumes, but which in general are more sophisticated and would require substantial effort to implement.

TABLE 4-1 Summary of options for improving transportation modeling.

General Improvements to Travel Demand Forecasting (A)	General Procedural Improvements (B)	Factoring and Cross-Classification Processes (C)	Intractable Problems & Statistical Limitations (D)	Modifications to Models to Specifically Address Air Quality (E)
A-1 Intersection delay modeling	B-1 Bracketing (all parameters)	C-1 Relating fleet mix to network characteristics	D-1 Need to bracket statistical limitations	E-1 Estimation of emission for transit using public transit models (also estimation of transit access mode); need to consider non-revenue transit trips
A-2 Weekend and episodic modeling	B-2 Conduct speed surveys to better validate models	C-2 Match fleet to trip type	D-2 Transportation control measures (TCMs)	E-2 Further disaggregation of zones (rural/suburban areas)
A-3 Integration of transit and highway networks		C-3 Time-specific fleet distribution		E-3 Speed inputs based on cross-classification of network characteristics
A-4 Analytical land use forecasting processes (DRAM/EMPAL)		C-4 Diurnal speed profiles		
A-5 Consideration of congestion in choosing destinations		C-5 "Correcting" speeds based on V/C ratio (TRFCONV)]		
A-6 Better "peak spreading" characterization		C-6 Deal with off-network speeds/VMT, based on socioeconomic data		
A-7 Improve HOV models		C-7 Cross-classification of parking duration by zone/trip ends		
A-8 Reestimate O&D information using observed traffic volumes				
A-9 Queuing models for toll stations				
A-10 Integration with GIS databases				

2. Philosophical Perspective (General Procedural Improvements). These are procedures that would generally be simple to implement, although they might require additional survey data, as would be the case if models were calibrated against observed speeds as well as volumes.

3. Factoring and Cross-Classification Processes (Post-Processing Data into Look-Up Tables). These procedures are relatively simple to implement, and the implementation process is relatively uniform for each suggested improvement. These are generally post-processing steps which would allow air quality modelers to have more detailed information available for producing emission inventories. Many of these suggestions can only be demonstrated in the prototype testing mode, since they rely upon survey data which, while generally simple to gather, is available for few existing models.

4. Intractable Problems and Statistical Limitations. Rather than procedures, these are problems which, due to statistical limitations of data used in developing these models, cannot be addressed with the current generation of transportation models.

5. Reworking Transportation Models to Specifically Address Air Quality Issues. These procedures would require recoding of existing transportation models so that they would directly provide more of the information which is required by air quality modelers in developing emission estimates. An example of such a procedure would be coding models to report link-specific transit vehicle travel.

General Improvement to Travel Demand Forecasting

Ten optional procedures have been suggested which fall within the category of providing general improvement to travel demand forecasting using available tools which, due to their complexity, are often not utilized in transforation models. For reference, these procedures have been labeled in Table 4-1 as A-1 through A-10.

Option A-1, Intersection Delay Modeling. This type of modeling would require incorporation of signalization models, such as FHWA's TRAF-NETSIM, into the overall transportation model, in order to capture the effects of intersection queuing on overall travel times and link impedances. Although a variety of signalization models are available, it would be a complex effort to actually merge the two types of models. Some research has currently been proposed in this direction by the California Air Resources Board, which is initiating an effort to study the feasibility of incorporating signalization models into transportation models.

Option A-2, Weekend and Episodic Modeling. This type of modeling requires no new modeling tools but would require expansion of origin and destination surveys and ground count and/or speed calibration data in order to gather data pertinent to weekends, seasons, and/or particular episodes. What is envisioned here is the gathering of data sufficient to demonstrate the statistical accuracy of such a model. The result of this effort would be model outputs more representative of the typical travel activity a region might experience during a particular season or day of week or time of day. This would be of most use in areas which attract seasonal recreational activity, such as skiing or tourism. Another practical result is gained if models specific to weekend and weekday travel activity can be developed, since air quality episodes are not limited to weekdays and photochemical (ozone) models require hourly inputs.

Option A-3, Integration of Transit and Highway Networks. This can be achieved using existing models and is not resource intensive. It allows modeling the effects of congestion on transit travel times, and by extension on mode choice. This is one of the strategies demonstrated in this project using the TRANPLAN program INET (adapted from UTPS software), and is discussed in more detail later in this chapter.

Option A-4, Analytical Land-Use Forecasting Processes. This is still a resource-intensive process. Models such as DRAM/EMPAL have been developed for this procedure, which refine the landuse forecasts used to develop regional transportation models. At present, these models are still relatively resource intensive to use and difficult to calibrate (past growth patterns are used for calibration).

Option A-5, Consideration of Congestion in Choosing Destinations. This is a feedback step which allows modeling the impacts of longer travel times on destination choice. It is relatively simple to implement. Trips for selected trip purposes are redistributed after the highway assignment process based on congested travel times. This is one of the strategies demonstrated in this project, and is discussed in more detail later in this chapter.

Option A-6, Better Characterization of "Peak Spreading". This technique is used to overcome the problem of predicted volume to capacity ratios exceeding one. Some simple procedures using adjustments based upon peak period volume to capacity ratios by link were developed to attempt to reduce this problem as part of research conducted by the Arizona Department of Transportation (Loudon et al., 1988), but research still continues to develop more accurate methods to represent the phenomenon.

Option A-7, Improved HOV Models. Improving HOV models is an ongoing topic of research in the transportation modeling community. This becomes more important as regions are forced to evaluate TCM packages as part of their response to new legislative requirements, such as the CAAA. Improving models to include the effects of other CAAA-mandated TCMs is also a matter of continuing research.

Option A-8, Reestimation of Origin and Destination (O-D) Matrices Using Observed Traffic Volumes. A variety of different techniques using different combinations of traffic and transport data are currently in use for creating O-D matrices. Although caution must be exercised when using observed traffic volumes for this purpose, due to the stochastic nature of the observations, this method has been successfully applied (Hammerslag, 1980).

Option A-9, Using Queuing Models for Toll Stations. Use of queuing models is similar in complexity to the use of intersection delay models.

Option A-10, Integration with GIS Data bases. This can be particularly useful for incorporating information from various data bases, such as the U.S. Census TIGER files, into land-use characterizations. For many agencies, this option is still unworkable due to the resources required to effectively use GIS.

General Procedural Improvements

Two procedures have been suggested which fall within the category of being relatively simple procedures which may, however, require more extensive survey data than is usually available. For convenient reference, these procedures have been labeled in Table 4-1 as B-1 and B-2.

Option B-1, Bracketing of All Parameters, is a simple exercise which can be conducted by the transportation modeler. Inputs to the model, such as speed, can be set to the extreme values of the anticipated variation which would be seen for these inputs. The outputs produced by such an exercise express the range of variability which can be attributed to the specific model input.

Option B-2, Conduct Speed Surveys to Better Validate Models. This is another technique which would require more extensive survey data than is frequently collected for a transportation model.

Factoring and Cross-Classification Processes

Seven procedures have been suggested in Table 4-1, labelled as C-1 through C-8, which are predominantly post-processing steps for the model outputs rather than actual changes in modeling procedure. Many require more extensive socioeconomic and origin and destination survey data than is commonly collected.

Option C-1, Relating Fleet Mix to Network Characteristics. This would rely upon survey information to better characterize the vehicle fleet composition expected on specific facility types or subregions. This would allow a better match of emission rates to vehicle activity for these links or zones. One near-term solution might be to use tube counters that differentiate between light vehicles and heavy vehicles, and use local registration distributions or national defaults to split those groups. In the future, one might be able to rely on automatic vehicle identification equipment placed on selected travel routes.

Option C-2, Relate Fleet Characteristics to Specific Trip Types. This is similar to option C-1. It would develop trip tables for specific fleets, such as heavy-duty vehicles. Such tables would vary by time of day, day of week, and facility class. This allows a better match of emission rates to vehicle activity for this trip type. It does require the transportation model to report travel activity by trip type and zone/link.

Option C-3, Time-Specific Fleet Characterization. This is similar to the previous options in this category. It would use origin and destination survey data to alter average fleet characteristics by time of day, in order to better match emission rates to travel activity. The emission changes which can be seen from changing fleet characteristics are illustrated with a sample model run discussed later in this chapter.

Option C-4, Diurnal Speed Profiles. This would change the speeds input to the transportation model based upon time of day. For example, if model runs were performed for peak and off-peak periods, one would use congested and freeflow speeds for the two runs, respectively.

Option C-5, Correcting Speeds Based on V/C Ratios. This is a post-processing step (although it could also be combined with feedback) which has been applied in air quality modeling conducted for Phoenix (SAI, 1987). It serves to eliminate the problem of V/C ratios exceeding one, but may be an overly simplistic remedy as it is presently applied since there is no feedback to the assignment or mode choice process. A thorough discussion of this technique has been provided in a recent paper by Cambridge Systematics (CSI, 1991).

Option C-6, Use Socioeconomic Data for Developing Off-Network Speeds/VMT. This is intended to provide better characterization of intrazonal travel, but relies upon the availability of adequate survey data and interpretive skills in arriving at more accurate estimates of this travel activity.

Option C-7, Cross-Classification of Parking Duration by Zone. This would allow better characterization of vehicle starts into hot and cold starts, and better characterization of the magnitude of resting losses and diurnal evaporative emissions from parked vehicles. This type of information is not currently being provided by transportation models, and still requires some developmental work.

Intractable Problems and Statistical Limitations

This category is not a list of suggested procedures but instead groups two problems facing transportation modelers which currently cannot be handled effectively either because of the complexity of the issue or because of statistical limitations within the model. Referred to as **options D-1 and D-2**, these are respectively, identifying the statistical limitations and absolute uncertainty of model outputs, and properly modeling the effects of transportation control measures (TCMs).

TCMs are particularly important at this time due to legislative requirements, including the CAAA, which are forcing regions to develop TCM packages. Since many TCMs, such as telecommuting, affect a very small percent of total travel activity, statistical limitations inherent in the data used to develop transportation models do not allow the effects of such measures to be accurately predicted by the models.

Modifications to Models to Address Air Quality

Three options are provided in this category. All require recoding of existing transportation models to implement, but the result would be that models would provide information which is better suited to the needs of air quality modelers. These options are referred to as E-1 through E-3 in Table 4-1.

Option E-1, Estimation of Transit Emissions Using Public Transit Models. This represents a refinement of the usual treatment of transit activity in transportation models in that a model specifically developed for representation of transit activity would be integrated into the transportation model. Ideally, such a model would provide link and zone based estimates of transit activity (including non-revenue producing activity).

Option E-2, Further Disaggregation of Zones. This is intended to allow more specific tailoring of the region covered by a transportation model to the region of interest in air quality modeling. Ideally, the level of detail in outlying areas of the modeled region, which can serve as important sources of emissions due to transport, would be as detailed as could be practically managed, given the statistical accuracy of databases. Simplification of the network in these outlying areas would not occur in order to conserve resources, but only when data were not available to support a more detailed treatment.

Option E-3, Speed Inputs Based on Cross-Classification of Network Characteristics. This is similar to option C-6, which applied to assumptions for intrazonal travel. This suggested procedure would refine the methods used in assigning initial speeds to each link in a network to take into account more information on the actual network. This information could include the occurrence of episode specific events, such as roadway construction, which would have significant effects on a subset of links in a network.

DEMONSTRATION OF SELECTED PROCEDURES

As mentioned earlier, three of the options described above have been demonstrated using a prototypical transportation model developed for this project. Use of a prototypical model allowed demonstration of a wider range of potential improvements to the transportation model process within the resources allocated for this effort, and given the absence of survey data required to actually implement many of these suggested procedures. The model was developed by drawing from data bases established for existing models and uses the TRANPLAN version 7.0 and NIS version 3.0 model software (UAG, 1990). The exercises conducted with this prototypical model serve as demonstrations of how these procedures can be implemented and confirm that the effects can be significant. They do not quantify the actual magnitude of change to be expected from their implementation in an urban transportation model. The prototypical network used here is too small and conditions on it, particularly in terms of congestion, too unrepresentative to allow one to assume that these results are indicative of results that would be obtained with an actual urban transportation model. In future work, the EPA may use actual urban transportation models to obtain more realistic estimates of the effectiveness of some of these techniques.

Description of Base Case

The transportation network used in these modeling exercises represents a simplified prototype network. The highway network geometry consists of 27 zones, 190 links, and has a maximum node number of 317. The geometry of the transit portion of the network contains the same number of zones, but has 174 links and a maximum node number of 314. Figures 4-1 and 4-2 are graphical representations of these networks. Appendix A contains a summary of the land-use data used by the model.

The initial step in our analysis was to generate a base transportation network using the TRANPLAN transportation modeling software. Figure 3-3 is a flow diagram of the basic modeling procedure. Note that any modules not enclosed in the thick border are add-on applications to the core modeling software. This modeling exercise provided baseline values to be used for comparison in the test exercises detailed below. Note that in the base case feedback is not used to reflect the effects of congestion on trip length and speeds in both the highway and transit networks. Options A-3, A-5, and C-1 (see Table 4-1) were chosen for modeling. The overall results of these modeling exercises are given in Table 4-2.

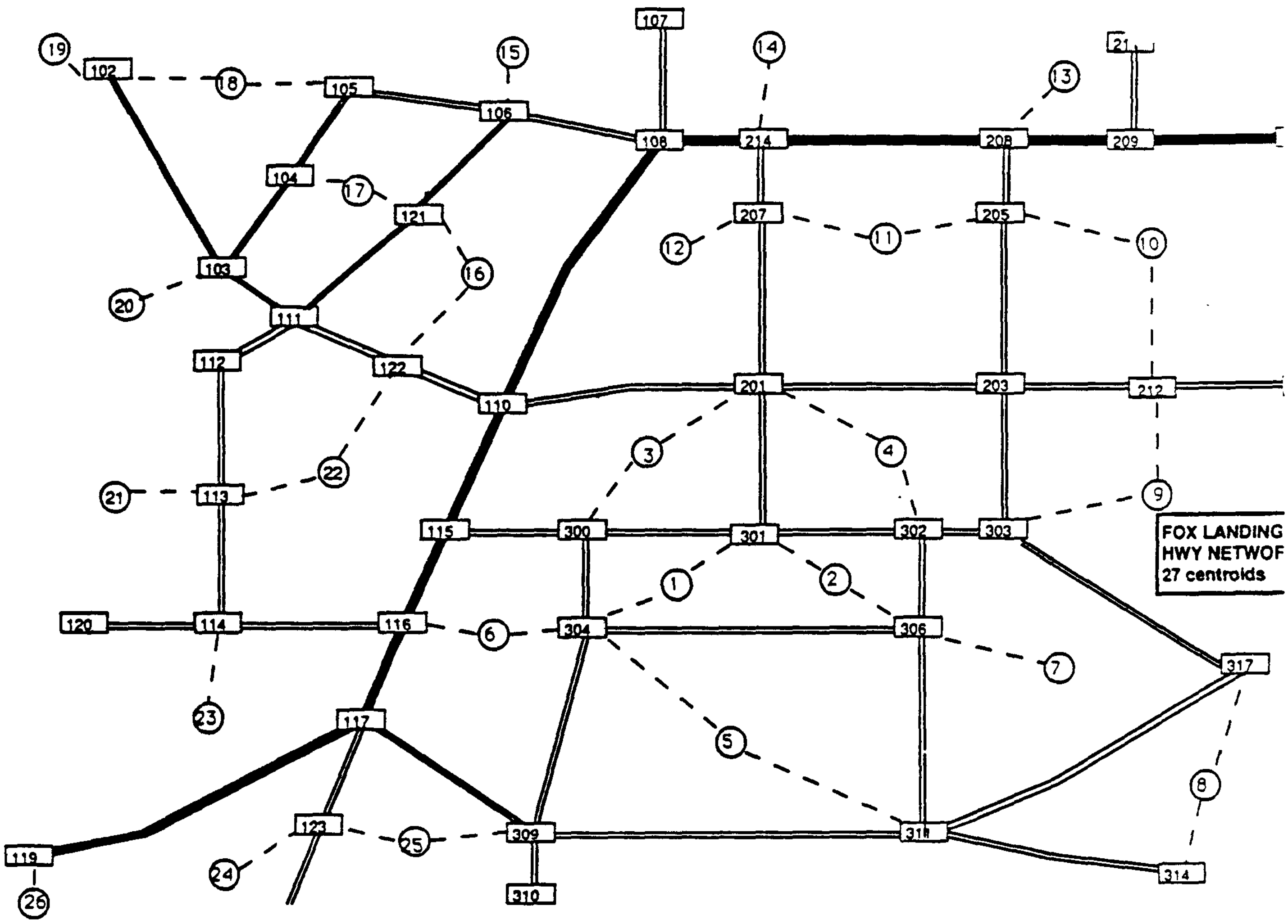


FIGURE 4-1. Highway network employed in sample model runs.

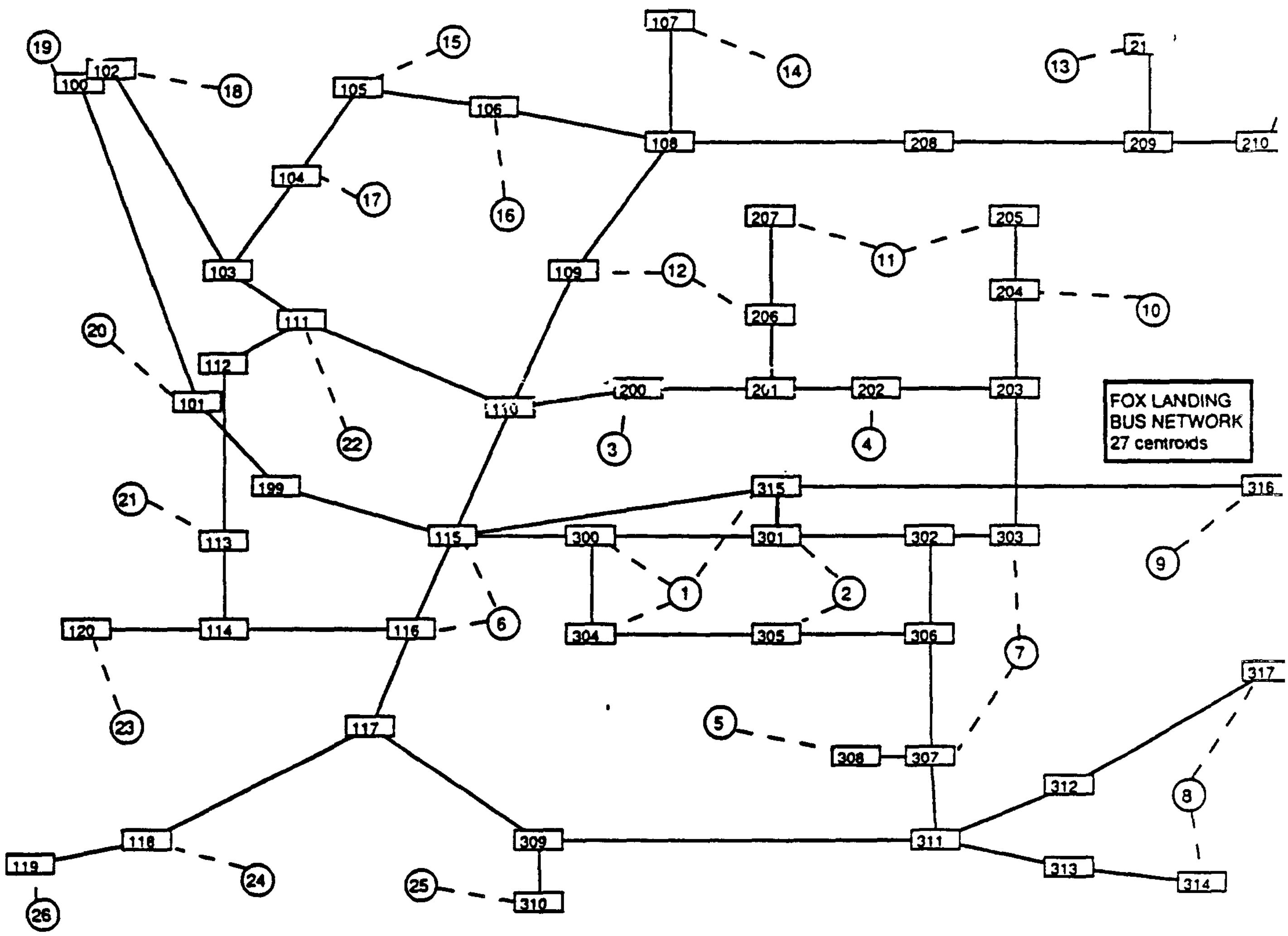
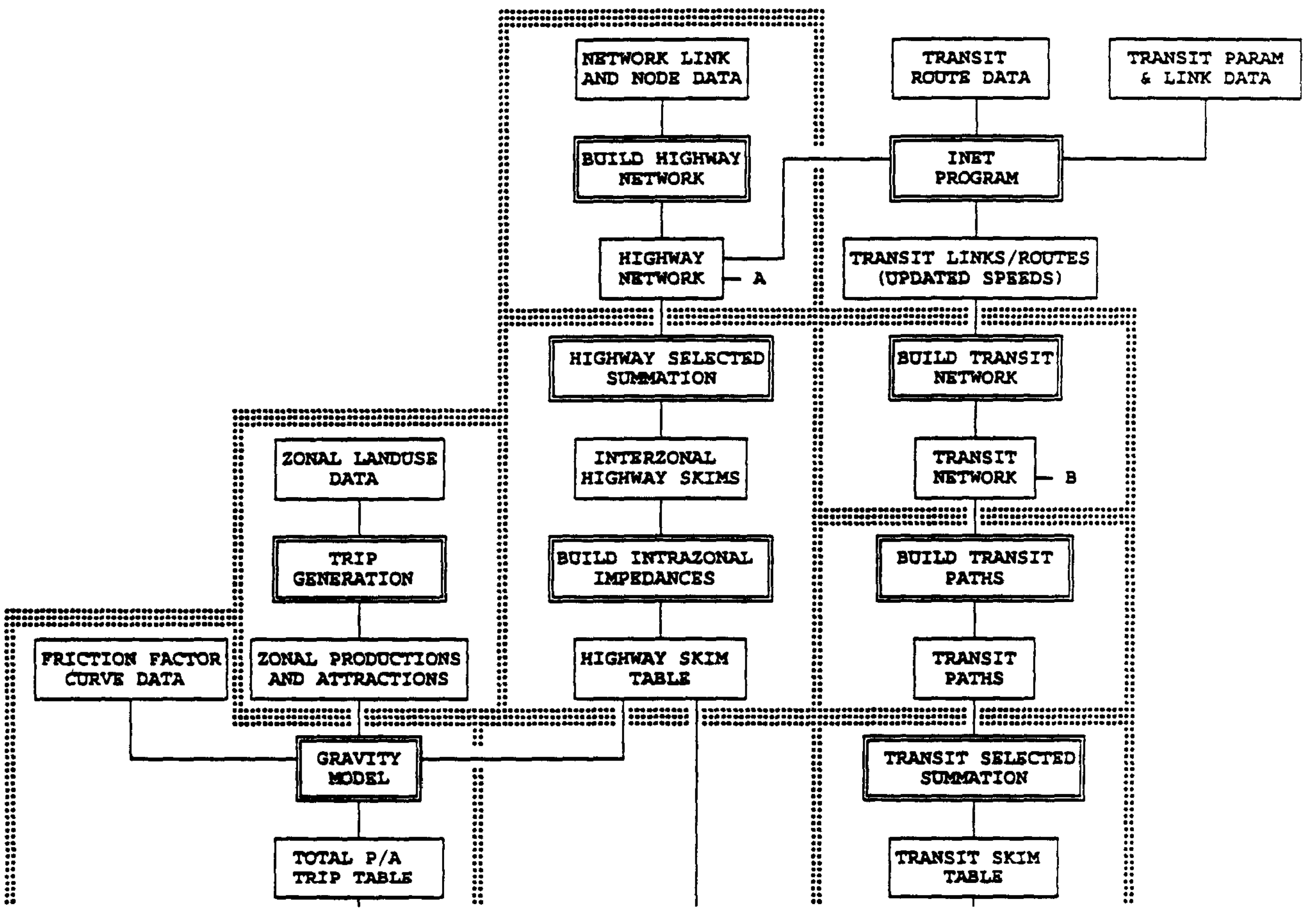


FIGURE 4-2. Transit network employed in sample model runs.



(continued next page)

FIGURE 4-3. Structure of prototypical transportation model. The model components are described in the TRANPLAN user's manual (Urban Analysis Group, 1990).

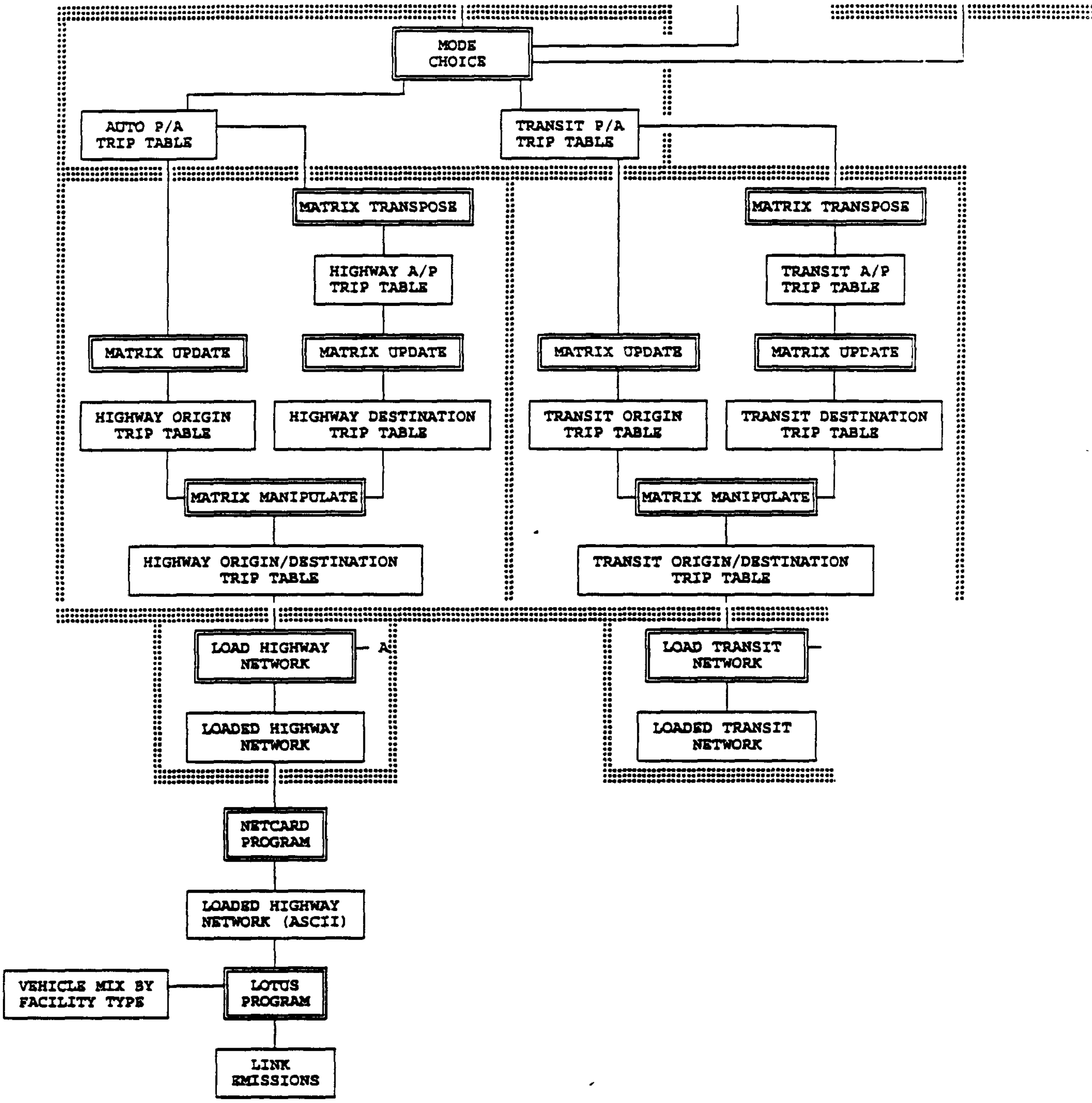


FIGURE 4-3. Concluded.

92004

TABLE 4-2. Summary of modeling exercise results.

Modeling Exercise	Speed Conditions		Observed Change in				
	Highway	Transit	Trips	VMT	Time	Speed	Emissions
A-3	Free	Congested	−20%	−27%	−13%	Lower	Lower
A-5							
Highway	Congested	Free	+1%	Higher	Higher	Lower	Mixed
Transit			−5%	Lower	Lower	Lower	Mixed
C-1	N/A	N/A	N/A	N/A	N/A	N/A	Lower

Option A-3: Use Transit Speeds that Reflect Congested Roadway Conditions

In initial base case free-flow speeds are applied to both the highway and transit networks. In this exercise the loaded highway network file produced in the base case run was input into the INET* module to generate transit speeds that would reflect congested roadway conditions. The effects of this procedure on passenger trips, miles traveled, and travel time can be seen in Table 4-3.

TABLE 4-3. Results of Option A-3 on transit trips, miles, and hours of travel.

TRANPLAN Model Run	Passenger		
	Trips	Miles	Hours
Base Case	4172	4401	956
Option A-3	3330	3191	827
% Difference	− 20 %	− 27 %	− 13 %

All three transit usage variables exhibit significant reductions when the loaded highway network is used as input to INET. This occurs because modeling transit choice with congested rather than free-flow speeds reduces its attractiveness.

* INET is a transit network program released by the U.S. Department of Transportation for use with the Urban Transportation Planning System (UTPS) software. Its principal task is to calculate transit running times. INET computes transit speeds as a linear function of highway speed.

Option A-5: Examine the Impact of Using the Loaded Highway Network

In this test case, the loaded highway network generated by the base run was input in to the Highway Selected Summation stage of the modeling process, replacing the Build Highway Network step used initially (see Figure 4-3). The predicted effect of this procedure is that the average trip times would increase, reflecting the congested highway speeds. This will affect the trip distribution, mode choice, and trip assignment processes. In the base case, free flow speeds were used. Table 4-4 summarizes the results of this exercise.

As illustrated by Table 4-4, the apparent effect of this test case on trip times is negligible. This prompted further examination of modeling outputs, as it was expected that there would be noticeable changes using the loaded highway network. These results are described in greater detail below.

The next model run is an extension of the two procedures described above. In this exercise, the loaded highway network from the base transportation model run was first input into both INET and the Highway Selected Summation phases of the model, and then the modeling process was run to its conclusion. The predicted effect of this method was that the congested highway speeds would affect both the highway and transit networks at the mode choice level. It was predicted that the increase in travel time on the transit network would result in a decrease in transit usage, and subsequently an increase in automobile trips. Table 4-5 illustrates the results of this mode choice comparison.

As Table 4-5 illustrates, there is a shift in the trips from transit to the highway network when congested speeds are input into the transit network. These changes are fairly small, however we believe that a larger, more complex transportation network would exhibit more widespread and significant changes in mode choice.

Another result of this experiment was a subtle change in the origins/destinations and volumes of trips at the zonal level. Appendix B contains the Report Matrix Comparison output which contrasts the origin/destination tables of the base case with those from this sample model run. In nearly every zone, changes in the number of trips is evident. The degree of change is very zone-dependant. Particularly dramatic changes (greater than 10%) in trip origins/destinations are evident in zones 12, 13, 15, 17, 20, and 25. Significant (greater than 10%) changes in volumes are also seen in the aforementioned zones, as well as zones 9, 16, 18, 21, 22, 26, and 27. These changes occur because congested speeds increase travel time disproportionately across the region, making some zones less attractive to travel to. This results in a shift in the distribution of origins and destinations. Trips are shifted onto shorter pathways, potentially resulting in increased intrazonal travel.

TABLE 4-4. Effects of congested highway speeds on trip distribution by trip type.

Trip Type*	Trip-Hours	Average Trip Length (min)
Type 1 (Base)	3255	16.222
Type 1 (Option A-5)	3270	16.293
% Difference	0.005 %	0.004 %
Type 2 (Base)	6522	15.039
Type 2 (Option A-5)	6559	15.124
% Difference	0.007 %	0.007 %
Type 3 (Base)	2702	12.007
Type 3 (Option A-5)	2700	11.997
% Difference	0	0

* Trip type 1 = home-based work
Trip type 2 = home-based other
Trip type 3 = non-home based

TABLE 4-5. Effects of congested speeds on mode share.

TRANPLAN Test Case	Origins/ Productions	Destinations/ Attractions	Total
Highway Trips Summary			
Base Case	24,354	24,354	48,708
Option A-5	24,695	24,695	49,390
% Difference	1 %	1 %	1 %
Transit Trips Summary			
Base Case	8,128	8,128	16,256
Option A-5	7,722	7,722	15,444
% Difference	− 5 %	− 5 %	− 5 %

Option C-1: Postprocessing of Link-Based Travel to Estimate Emissions

In this example, MOBILE 4.1 NO_x emission rates and vehicle fleet mix information are combined with data from the Loaded Highway Network file to estimate link-level NO_x emissions. This exercise illustrates the importance of matching fleet mix characteristics to roadway class in estimating emissions for a region, and also illustrates the effects of speed on vehicle emission rates.

Emission rates used correspond to a 1991 calendar year fleet in wintertime conditions (minimum temperature of 20 F, maximum of 40 F). Two fleet mixes were modeled in this exercise, one using a VMT by vehicle class distribution which is based upon national averages, referred to as "Default" in subsequent tables, and the other reflecting the arbitrary reduction in VMT attributed to heavy duty vehicles (both gasoline and diesel), with a concurrent increase in the VMT attributed to light duty gas vehicles. This second scenario is intended to roughly represent the fleet characteristics found on residential streets, although the numbers given are provided purely for the purposes of demonstration, and as such are not based upon actual survey data. This second fleet mix is referred to as the "Reduced HDV" in subsequent table. Table 4-6 summarizes the fleet mixes and emission rates used.

Three scenarios are considered. In the first, the default fleet mix is used to calculate the fleet average emission rate, which is then applied to all travel on the network to calculate total NO_x emissions. The second uses the reduced HDV fleet mix to calculate the fleet average emission rate, which is then applied to all travel on the network to calculate total NO_x emissions. The final scenario uses the default fleet mix to calculate the fleet average emission rate applied to travel for facility types 0 and 1, and the reduced HDV fleet mix to calculate the fleet average emission rate applied to travel for facility type 2. Table 4-7 is an example of the spreadsheet developed for these link-based emission calculations, and Table 4-8 summarizes the fleet average emission rates, VMT accumulation, and emissions by speed range, facility type, and scenario.

As would be expected, the greatest difference is seen between emissions calculated by assuming all travel in the model occurred with the default fleet mix as opposed to assuming it occurs with the reduced HDV fleet. The reduced HDV fleet produces approximately 40 percent less NO_x over the network than does the default fleet. However, since this is only a prototypical model, this exercise can only serve to indicate that fleet mix can significantly affect emissions estimates, and that the emissions will change significantly depending upon the speeds output by the model.

RECOMMENDED FOLLOW-UP

The resources of this project allowed only a small number of procedural improvements to actually be demonstrated with sample model runs using the prototypical model developed

Table 4-6. Summary of fleet mix and emission rates.

Vehicle Class	NO_x Rate (g/mi), 20 mph	NO_x Rate (g/mi), 50 mph	NO_x Rate (g/mi), 65 mph	Default Scenario VMT Distribution	Reduced HDV Scenario VMT Distribution
LDGV	1.74	1.65	2.57	.62	.669
LDGT1	2.15	2.11	3.29	.175	.224
LDGT2	2.69	2.75	4.27	.077	.077
HDGV	6.46	8.16	9.01	.035	.004
LDDV	1.65	1.74	2.88	.008	.008
LDDT	1.9	2.00	3.32	.002	.002
HDDV	17.52	18.44	30.54	.075	.008
MC	1.07	1.60	2.49	.008	.008

TABLE 4-7. Calculation of link-based emissions.

Link Information						No. of Vehicles			VMT			NO_x Emissions		
A Node	B Node	Facility	Distance	Speed(A-B)	Volume	LDGV	LDGT	HDGV	LDGV	LDGT	HDGV	LDGV	LDGT	HDGV
203	205	2	0.6	50	662	443	148	3	265.73	88.97	53.38	438.45	187.73	146.81
115	300	2	0.4	50	803	537	180	3	214.88	71.95	28.78	354.56	151.81	79.14
114	120	2	0.4	50	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
113	114	2	0.4	50	681	456	153	3	182.24	61.02	24.41	300.69	128.75	67.12
114	116	2	0.6	50	534	357	120	2	214.35	71.77	43.06	353.67	151.43	118.42
117	309	2	0.6	50	431	288	97	2	173.00	57.93	34.76	285.46	122.22	95.58
201	203	2	0.8	50	935	626	209	4	500.41	167.55	134.04	825.68	353.53	368.61
117	123	2	0.4	50	558	373	125	2	149.32	50.00	20.00	246.38	105.49	55.00
201	301	2	0.5	50	849	568	190	3	283.99	95.09	47.54	468.58	200.64	130.75
201	207	2	0.6	50	512	343	115	2	205.52	68.81	41.29	339.10	145.20	113.54
205	208	2	0.3	50	940	629	211	4	188.66	63.17	18.95	311.29	133.28	52.11
203	303	2	0.5	50	864	578	194	3	289.01	96.77	48.38	476.86	204.18	133.06
207	214	2	0.3	50	795	532	178	3	159.56	53.42	16.03	263.27	112.72	44.07
107	108	2	0.3	50	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
209	211	2	0.3	50	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
203	212	2	0.5	50	676	452	151	3	226.12	75.71	37.86	373.10	159.75	104.10
112	113	2	0.4	50	573	383	128	2	153.33	51.34	20.54	253.00	108.33	56.47
111	121	2	0.5	50	157	105	35	1	52.52	17.58	8.79	86.65	37.10	24.18
110	201	2	0.8	50	798	534	179	3	427.09	143.00	114.40	704.70	301.73	314.60
111	112	2	0.2	50	573	383	128	2	76.67	25.67	5.13	126.50	54.16	14.12
111	1222	2	0.3	69.23	736	492	165	3	147.72	49.46	14.84	379.63	162.72	133.69
108	2141	1	0.3	69.23	121	75	21	4	22.51	6.35	1.91	57.84	20.90	17.17

Continued

TABLE 4-7. Concluded.

Link Information						No. of Vehicles			VMT			NO_x Emissions		
A Node	B Node	Facility	Distance	Speed(A-B)	Volume	LDGV	LDGT	HDGV	LDGV	LDGT	HDGV	LDGV	LDGT	HDGV
115	1161	1	0.3	69.23	1539	954	269	54	286.25	80.80	24.24	735.67	265.82	218.40
116	1171	1	0.3	69.23	1552	962	272	54	288.67	81.48	24.44	741.89	268.07	220.24
208	2141	1	0.8	69.57	1139	706	199	40	564.94	159.46	127.57	1451.91	524.62	1149.39
108	1101	1	1	69.77	920	570	161	32	570.40	161.00	161.00	1465.93	529.69	1450.61
110	1151	1	0.5	69.77	128	79	22	4	39.68	11.20	5.60	101.98	36.85	50.46
117	1191	1	0.12	69.9	1453	901	254	51	108.10	30.51	3.66	277.83	100.39	32.99
209	2101	1	0.6	70.59	1086	673	190	38	403.99	114.03	68.42	1038.26	375.16	616.45
208	2091	1	0.4	70.59	1086	673	190	38	269.33	76.02	30.41	692.17	250.11	273.98
110	1222	2	0.2	70.59	928	621	208	4	124.17	41.57	8.31	319.11	136.78	74.92
											TOTAL	13470.15	5329.187	6155.967
									NOX EMISSIONS (GRAMS)			24955.3		
									NOX EMISSIONS(LBS)			54.91		

Table 4-8. Projected VMT and emission levels for comparison of fleet mixes.

	For VMT Accumulated at 20 mph	For VMT Accumulated at 50 mph	For VMT Accumulated at 65 mph
Fleet-Average NO_x Rate			
Default Fleet (g/mi)	3.234	3.308	5.161
Reduced HDV Fleet	2.045	1.999	3.112
Total VMT			
Facility Type 0 (Centroids)	1273	0	12872
Facility Type 1	0	0	4629
Facility Type 2	0	11156	1772
Total NO_x			
With Default Fleet (grams)	4116.9	36903.1	99468.9
With Reduced HDV Fleet (grams)*	2603.3 (-37%)	22300.2 (-40%)	59978.1 (-40%)
With Default Fleet on Facilities 0 & 1, Reduced HDV Fleet on Facility 2 (grams)*	4116.9 (0%)	22300.2 (-40%)	95838.3 (-4%)

* Numbers in parenthesis reflect percent change from default fleet emission levels.

92004r1.11

for this effort. It would be useful to explore the potential benefits of some of the other procedures listed in Table 4-1 further in future modeling work using the prototypical model as well as actual travel demand networks. This would accomplish two goals: (a) demonstration of the practical utility of a procedure and (b) demonstration of the anticipated effects of a procedure. In short, further modeling efforts can answer the questions of whether an idea can actually be implemented, and whether it would result in enough improvement in the model predictions to make it worth whatever extra resources are required for the implementation.

Future modeling work should not be limited to the ideas presented in this report. Given the number of concurrent research efforts ongoing in the field of transportation modeling, it would be worthwhile to select the best ideas from these other efforts also and assess their practical merit. For example, some of the suggestions anticipated from the ongoing work sponsored by the National Association of Regional Councils (Harvey and Deakin, 1991), as well as work in progress by Cambridge Systematics for Region IX of the EPA (CSI, 1991), would be interesting to investigate through actual model runs. The prototypical model that has been developed for this current work effort can be adapted for the demonstration of these ideas with the goal of determining their practicality and the anticipated benefits of their use.

References

Applied Management. 1990. "Traffic Congestion and Capacity Increases." Applied Management and Planning Group, Los Angeles, California.

Atkins, S. T., 1986. Transportation planning models--what the papers say. Traffic Engineering and Control, 27(9):460-467.

Cambridge Systematics, Inc. 1991a. "The Preparation of Highway Vehicle Emissions Inventories." Prepared for the Transportation Research Board 70th Annual Meeting, January 13-17, 1991, Washington, DC.

Cambridge Systematics, Inc. 1991b. "Development of Information on Transportation and Air Quality." Cambridge Systematics, Inc., Cambridge, Massachusetts.

CARB. 1990. "Derivation of the EMFAC7E Emission and Correction Factors for On-Road Motor Vehicles. California Air Resources Board, Mobile Source Division, Sacramento, California.

Deakin, E. 1991. "Seminar on Transportation Modeling for Emissions Analysis." Prepared for presentation June 20, 21, 1991, Sacramento, California, California Air Resources Board.

EPA. 1991. User's Guide to MOBILE4.1 (Mobile Source Emission Factor Model). U.S. Environmental Protection Agency (EPA-AA-TEB-91-01).

Hamerslag. R. 1980. "Spatial Development, Developments in Traffic and Transportation, and Changes in the Transportation System." In J. B. Polak and J. B. van der Kamp. Changes in the Field of Transport Studies. Martinus Nijhoff, The Hague.

Harvey, G., and E. Deakin. 1991. "Toward Improved Regional Transportation Modeling Practice." National Association of Regional Councils, Clean Air Project Transportation Modeling Conference, Washington, D.C.

Ireson, R. G., J. L. Haney, L. A. Mahoney, M. C. Dudik, J. L. Fieber, and D. R. Souten. 1987. "Carbon Monoxide Air Quality Modeling for the Phoenix Metropolitan Area--Emission Reduction Requirements and Control Measure Effectiveness." Systems Application, Inc., San Rafael, California (SYSAPP-87/059).

Ismart, D. 1991. "Travel Demand Forecasting Limitations for Evaluating TCM's." Air and Waste Management Association 84th Annual Meeting & Exhibition, Vancouver, BC.

Lorang, P. 1991. "Interim Guidance for the Preparation of Mobile Source Emission Inventories." Memorandum from Phil Lorang, Chief, Technical Support Staff, U.S. Environmental Protection Agency (January 31, 1991).

Meyer, M. D., T. F. Humphrey, C. M. Walton, K. Hooper, R. G. Stanley, C. K. Orski, and P. A. Peyser, Jr. 1989. "A Toolbox for Alleviating Traffic Congestion." Institute of Transportation Engineers, Washington, DC.

Ruiter, E. R. 1991. "Highway Vehicle Speed Estimation Procedures for Use in Emission Inventories." Cambridge Systematics, Inc., Cambridge, Massachusetts.

SAI. 1989. "Transportation Control Measures: State Implementation Plan Guidance". Systems Applications, Inc. San Rafael, California (SYSAPP-89/126).

Transportation Research Board. 1985. *Highway Capacity Manual.* National Research Council, Washington, D.C. (Special Report 209).

Urban Analysis Group. 1990. "TRANPLAN Version 7.0 and NIS Version 3.0 User Manuals." The Urban Analysis Group, Danville, California.

Appendix A

CHARACTERISTICS OF PROTOTYPICAL MODEL

1. FoxLandUse 1

Zone Type	Zone No.	Inhabitants: Flats	Inhabitants: One-fam.	Econ. Active	JOBS: Ind.	JOBS: Retail	JOBS: Office	JOBS: Misc.	JOBS Total
CBD	01	1000	0	480	0	1000	2000	400	3400
CBD	02	2000	0	960	0	1000	1050	600	2650
CBD-Sum		**3000**	**0**	**1440**	**0**	**2000**	**3050**	**1000**	**6050**
Industr.	21	0	0	0	2000	0	0	0	2000
Industr.	23	0	0	0	1500	0	0	0	1500
Industr	28	0	0	0	1500	0	0	0	1500
Industr.	33	0	0	0	1000	0	0	0	1000
Ind-Sum		**0**	**0**	**0**	**6000**	**0**	**0**	**0**	**6000**
Mixed	12	3500	500	1625	600	140	600	300	1640
Mixed	13	3000	0	1230	850	100	700	400	2050
Mixed	14	1200	300	605	400	0	200	0	600
Mixed	25	2000	0	820	1200	100	500	0	800
Mix-Sum		**9700**	**800**	**4280**	**3050**	**340**	**2000**	**700**	**6090**
Res.Flats	10	2500	0	1025	0	0	50	0	50
Res.Flats	11	2400	0	985	0	20	0	0	20
Res.Flats	24	1500	0	615	0	0	0	0	0
Res.Flats	26	2000	300	935	0	220	150	100	470
Res.Flats	29	1000	0	410	0	0	0	0	0
Res.Flats	30	2600	400	1220	0	50	150	100	300
Res.Flats	32	3200	800	1615	0	30	50	0	80
Res.Flats	34	3000	0	1230	0	20	0	0	20
Res.Flats	35	2800	0	1150	0	0	50	0	50
Res.Flats	36	3000	200	1305	0	200	300	100	600
Flats-Sum		**24000**	**1700**	**10490**	**0**	**540**	**750**	**300**	**1590**
Res.OneF.	22	0	1800	685	0	30	0	0	30
Res.OneF.	27	0	1200	455	0	20	0	0	20
Res.OneF	31	0	2000	760	0	20	50	0	70
Res.OneF	37	0	3000	1140	0	50	200	0	250
OneF-Sum		**0**	**8000**	**3040**	**0**	**120**	**250**	**0**	**370**
TOTAL		**36700**	**10500**	**19250**	**9050**	**3000**	**6050**	**2000**	**20100**

Incoming commuters from

		Econ. Active	JOBS Total
External zone	101	1000	
	102	550	

Outgoing commuters to

		Econ. Active	JOBS Total
External zone	101		300
	102		400
Grand Total		**20800**	**20800**

2. FoxLandUse 2

Re-edited in accordance with limitations in TRANPLAN.

		INHABITANTS			INDUSTRY		RETAIL		OFFICE		MISC.
Zone	**no.**	**CBD**	**Flat**	**House**	**Large**	**Small**	**CBD**	**Other**	**CBD**	**Other**	
(01)	1	1000	0	0	0	0	1000	0	2000	0	400
(02)	2	2000	0	0	0	0	1000	0	1050	0	600
(12)	3	0	3500	500	0	600	0	140	0	600	300
(13)	4	0	3000	0	0	850	0	100	0	700	400
(10)	5	0	2500	0	0	0	0	0	0	50	0
(11)	6	0	2400	0	0	0	0	20	0	0	0
(14)	7	0	1200	300	0	400	0	0	0	200	0
(38)	8	0	0	0	0	0	0	0	0	0	0
(37)	9	0	0	3000	0	0	0	50	0	200	0
(36)	10	0	3000	200	0	0	0	200	0	300	100
(34)	11	0	3000		0	0	0	20	0	0	0
(32)	12	0	3200	800	0	0	0	30	0	50	0
(35)	13	0	2800	0	0	0	0	0	0	50	0
(33)	14	0	0	0	1000	0	0	0	0	0	0
(31)	15	0	0	2000	0	0	0	20	0	50	0
(30)	16	0	2600	400	0	0	0	50	0	150	100
(29)	17	0	1000	0	0	0	0	0	0	0	0
(28)	18	0	0	0	1500	0	0	0	0	0	0
(27)	19	0	0	1200	0	0	0	20	0	0	0
(20)	20	0	2000	300	0	0	0	220	0	150	100
(24)	21	0	1500	0	0	0	0	0	0	0	0
(25)	22	0	2000	0	0	1200	0	100	0	500	0
(23)	23	0	0	0	1500	0	0	0	0	0	0
(22)	24	0	0	1800	0	0	0	30	0	0	0
(21)	25	0	0	0	2000	0	0	0	0	0	0
Ext	26	0	0	0	0	0	0	0	0	0	0
Ext	27	0	0	0	0	0	0	0	0	0	0
Total		**3000**	**33700**	**10500**	**6000**	**3050**	**2000**	**1000**	**3050**	**3000**	**2000**

		Col 11	Col 12	Col 13	Col 14
(38)	8	1000	0	0	0
(101)	26	0	1000	300	3830
(102)	27	0	550	400	3145
Total		**0**	**1550**	**700**	**6975**

Figures in the four last columns do not refer to any explicit land use category. For all other zones than the mentioned 8,26, and 27 the values are 0 in these columns.

The forecast example will be carried out as a traditional application of the four-step gravitational model. Data and parameters are purely fictitious but reasonable. Some parts of the approach are a little more sophisticated than is usually used; the intention is to get familiar with the possibilities of TRANPLAN and get ideas for the combined system VIPSPLAN.

3.1 Travel purposes

The trip production and the zonal distribution are carried out in the form of three one-directional trip matrices:

Home to Work
Home to Visit
Non-home to Visit

3.2 Notes to the land use table

The Land use table is first given in a form that is rather common in this type of studies. It is then re-edited according to the conventions in TRANPLAN.

The rate of economically active population is for people living in

CBD	48 %
Flats	41 %
One-family houses	38 %

The external area consists of the two zones 101 and 102.

In-coming commuters from	zone 101:	1000
	zone 102:	550
Out-going commuters to	zone 101:	300
	zone 102:	400
Total number of trips to / from	zone 101:	10000
	zone 102:	8000

3.3 Definitions

Trip is here defined as a movement from Origin to Destination **by car or public transport.**

A commuter is a person with a given home zone and a given work zone (within or outside the city.) This zonal combination results in a trip a particular day only if the person really goes to work that day and does it by car or public transport.

3.4 Assumed trip rates

Trip production per day and person normally varies with various socio - economical factors etc. These factors are here represented by **type** and **location** of the home.

Average trip rate per person living in CBD is 1.5 and for the rest 2.0. Residents in houses have a trip rate that is 25 % higher than those in flats. This gives the following rates and number of trips by the inhabitants of Fox Landings:

	Trip rate	Number of trips
Residents in CBD	1.5	4 500
Residents in flats	1.92	64 700
Residents in houses	2.40	25 200
Total		**94 400**

3.5 Trips across the border line

The Home / Work relations can be written in the following matrix form:

WORK / HOME	FOX LANDING	EXTERNAL ZONES	TOTAL
FOX LANDING	18550	700	19250
EXTERNAL Z.	1550	0	1550
TOTAL	20100	700	20800

In order to transform these figures into trips the following assumptions are made:

10 % are absent from work on an average day.
60 % of the internal and all the external commuting is made by car or transit.

This corresponds to the following generation and attraction factors for the home-work trip matrix:

> **Generation:** 0.9 x 0.6 = 0.54 applied to the value of economically active population in each internal zone and 0.9 applied to the value of incoming commuters.
> **Attraction:** 0.54 applied to the number of jobs in each zone and 0.9 applied to outgoing commuters.

Then the Home Work trip matrix (both directions) will be:

WORK / HOME	FOX LANDING	EXTERNAL ZONES	TOTAL
FOX LANDING	20034	1260	21294
EXTERNAL Z.	2790	0	2790
TOTAL	22824	1260	24084

The remaining trips (not Home-Work) we call "visiting trips" or "non-work trips". Such trips between Fox Landing and the external zones amount to

18000 - 1260 - 2790 = 13950.

50 % of these are supposed to be produced by the people in the city and 50 % by external people. Thus the city inhabitants make 94400 - 21294 = 73106 non-work trips. The double directed matrix can be written

TO / FROM	FOX LANDING	EXTERNAL ZONES	TOTAL
FOX LANDING	66125	6975	73100
EXTERNAL Z.	6975	0	6975
TOTAL	73100	6975	80075

3.6 Distribution on trip generators

The total number of trips is assumed to be generated as follows:

Dwellings	65 % = 47515
Work	20 % = 14620
Visit	15 % = 10965
SUM	100 % = 73100

With the same relative trip rate for different types of dwellings as above, the trip generation per inhabitant will be

CBD	0.755
Flats	0.966
Houses	1.208

14620 / 20100 = 0.727.

Generation in chains of visits is put equal for all kinds of visits. Each attracted visit consequently is assumed to generate

10965 / 73100 = 0.15 visiting trip.

Of the 73100 non-work trips 2000 are supposed to go to the recreation area in zone 38. This estimate has to be based on special considerations as land use in terms of dwellings or jobs does not exist or does not indicate the trip attraction. Thus 71100 trips have to be distributed on the attraction side according to the land use. The following assumptions are made:

Dwellings	20 %	(evenly distributed over all inhabitants)
Industry	15 %	(three times higher in mixed areas than in the heavy industrial zones)
Retail	25 %	(CBD -located shops generate twice as many visits per employee as the rest)
Office	20 %	(same relations as for retail)
Misc.	20 %	(the same for all zones)

The resulting attraction factors become:

Dwellings	0.301	per inhabitant
Industry (heavy)	0.704	per employee
(light)	2.112	-"-
Retail (CBD)	7.110	-"-
(other)	3.555	-"-
Office (CBD)	3.125	-"-
(other)	1.563	-"-
Misc.	4.740	-"-

All factors so far refer to round trips with the two trip legs identical. This does not present any difficulties for the construction of a trip matrix for one full day. However, if it is desired to build a matrix for a peak hour or some other dimensioning period of the day, it is better to create the matrices as one-directional flows. In the following calculations, therefore, half the generation and attraction factors given above will be used.

The number of trips between the forecast area and the surrounding world cannot be calculated from any land use as no such is given. It has to be estimated separately and then inserted as constants into the trip generation in TRANPLAN, four additional columns (11 - 14) were added to the FoxLandUse table only containing values for one or more of the zones 3 - 5. and 27.

Summary of trip generation factors

Variable (column)	Home to Work Gen.	Home to Work Attr.	Home to Visit Gen	Home to Visit Attr.
1	0.2655	0	0.3775	0.0978
2	0.2268	0	0.4830	0.0978
3	0.2102	0	0.6040	0.0978
4	0	0.54	0	0.2288
5	0	0.54	0	0.6864
6	0	0.54	0	2.3108
7	0	0.54	0	1.1554
8	0	0	0	1.0156
9	0	0.54	0	0.5080
10	0	0.54	0	1.5405
11	0	0	0	0.6500
12	0.9	0	0	0
13	0	0.9	0	0
14	0	0	0.3250	0.3250

Variable (column)	Work/Visit to Visit Gen.	Work/Visit to Visit Attr.
1	0.0226	0.0527
2	0.0226	0.0527
3	0.0226	0.0527
4	0.4163	0.1232
5	0.5219	0.3696
6	0.8968	1.2443
7	0.6301	0.6221
8	0.5979	0.5469
9	0.4807	0.2735
10	0.7190	0.8295
11	0	0.3500
12	0	0
13	0	0
14	0.1750	0.1750

3.7 Zonal distribution

The zonal distribution for the three matrices is calculated by means of a traditional gravity model with total travel time as impedance. The friction factors are calculated as weighted means of the impedance values in the skim tables from the highway and transit networks. As weights are used the approximate the rest. The formula reads.

$$f(d) = P \times d(tr)^a + (1.0 - P) \times d(car)^a$$

The values of "a" are:

Home - work	-1.5
Home - visit	-2.0
Non-home - visit	-2.5

Intrazonal trips and trips between the two external zones 26 an 27 are assumed to be = 0.

3.8 Modal split

3.9 Summing up to 24 hour trip matrices

3.10 Construction of max period matrices

Appendix B

COMPARISON OF OPTION A-5 RESULTS FOR HIGHWAY AND TRANSIT NETWORKS

Highway Network

J0310 92004

```
XX      XX  XXXXXXXXX   XXXXXXXXX     XXXXXX    XX      XX           XX   XXXXXXXX   XX      XX   XXXXXXXX
XX      XX  XXXXXXXXXX  XXXXXXXXXX   XXXXXXXX   XXX     XX          XX    XXXXXXXXXX   XX    XX    XXXXXXXXXX
XX      XX  XX      XX  XX      XX  XX      XX  XXXX    XX         XX     XX      XX    XX  XX    XX      XX
XX      XX  XX      XX  XX      XX  XX      XX  XX XX   XX        XX      XX              XX  XX    XX
XX      XX  XXXXXXXXXX  XXXXXXXXXX  XXXXXXXXXX  XX  XX  XX       XX       XXXXXXXXX      XXXX      XXXXXXXXX
XX      XX  XXXXXXXXX   XXXXXXXXXX  XXXXXXXXXX  XX  XX  XX      XX         XXXXXXXXX      XX        XXXXXXXXX
XX      XX  XX  XX      XX      XX  XX      XX  XX   XX XX     XX                 XX      XX              XX
XX      XX  XX   XX     XX      XX  XX      XX  XX    XXXX    XX          XX      XX      XX        XX      XX
XXXXXXXXXX  XX    XX    XXXXXXXXXX  XX      XX  XX     XXX   XX           XXXXXXXXXX      XX        XXXXXXXXXX
 XXXXXXXX   XX     XX   XXXXXXXXX   XX      XX  XX      XX  XX             XXXXXXXX        XX         XXXXXXXX

XXXXXXXXXX  XXXXXXXXX    XXXXXXXX   XX      XX  XXXXXXXXX   XX           XXXXXXXX   XX      XX
XXXXXXXXXX  XXXXXXXXXX  XXXXXXXXXX  XXX     XX  XXXXXXXXXX  XX          XXXXXXXXXX  XXX     XX
    XX      XX      XX  XX      XX  XXXX    XX  XX      XX  XX          XX      XX  XXXX    XX
    XX      XX      XX  XX      XX  XX XX   XX  XX      XX  XX          XX      XX  XX XX   XX
    XX      XXXXXXXXXX  XX      XX  XX  XX  XX  XXXXXXXXXX  XX          XX      XX  XX  XX  XX
    XX      XXXXXXXXX   XXXXXXXXXX  XX  XX  XX  XXXXXXXXX   XX          XXXXXXXXXX  XX  XX  XX
    XX      XX  XX      XXXXXXXXXX  XX   XX XX  XX          XX          XXXXXXXXXX  XX   XX XX
    XX      XX   XX     XX      XX  XX    XXXX  XX          XX          XX      XX  XX    XXXX
    XX      XX    XX    XX      XX  XX     XXX  XX          XXXXXXXXXX  XX      XX  XX     XXX
    XX      XX     XX   XX      XX  XX      XX  XX          XXXXXXXXXX  XX      XX  XX      XX
```

```
*************************************************************************************
*                                                                                   *
*                              MATRIX COMPARSION REPORTS                            *
*                                                                                   *
*          MATRIX COMPARE OF HIGHWAY O/D TABLES                                     *
*          (BASE CASE VS TEST CASE 3)                                               *
*                                                                                   *
*************************************************************************************
```

FILE CHARACTERISTICS

USER FILE IDENTIFICATION - HTRIPS.A3

FILE HEADER -------------- MATRIX COMPARE OF HIGHWAY O/D TABLES
(BASE CASE VS TEST CASE 3)

GENERATING FUNCTION ------ MATRIX MANIPULATE

TYPE OF FILE ------------- VOLUME

GENERATION FILE NAME ----- TMAN3

GENERATION DATE ---------- 02JAN92 CURRENT DATE ---------- 07JAN92

GENERATION TIME ---------- 15:48:15 CURRENT TIME ---------- 14:36:45

FILE SIZE ---------------- MAXIMUM ZONE = 27

MAXIMUM TABLE NO. = 1

UAG - URBAN/SYS
TRANPLAN SYSTEM
VERSION 7.0

MATRIX COMPARE OF HIGHWAY O/D TABLES
(BASE CASE VS TEST CASE 3)

PAGE NO. 1
DATE 07JAN92
TIME 14:36:45

VOLUME COMPARISON REPORT ---- VOLUME DIFFERENCES AND RATIOS.

MAXIMUM CENTROID NUMBER = 27 NUMBER OF PURPOSES = 1

ORIGIN ZONE 1 PURPOSE 1

	ZONE	1	2	3	4	5	6	7	8	9	0
TAPE 1	1	0	377	168	99	136	126	33	12	67	48
TAPE 2		0	379	171	104	135	127	34	11	68	50
DIFF.		0	-2	-3	-5	1	-1	-1	1	-1	-2
RATIO		.00	1.01	1.02	1.05	.99	1.01	1.03	.92	1.01	1.04
TAPE 1	11	55	82	49	10	35	45	13	14	23	36
TAPE 2		35	88	56	10	43	46	17	16	22	39
DIFF.		20	-6	-7	0	-8	-1	-4	-2	1	-3
RATIO		.64	1.07	1.14	1.00	1.23	1.02	1.31	1.14	.96	1.08
TAPE 1	21	16	37	17	29	56	101	78			
TAPE 2		18	39	19	26	57	101	78			
DIFF.		-2	-2	-2	3	-1	0	0			
RATIO		1.13	1.05	1.12	.90	1.02	1.00	1.00			

SEPARATION COMPARISON REPORT ---- FREQUENCY DISTRIBUTION (V1-V2).
MAXIMUM CENTROID NUMBER = 27 NUMBER OF PURPOSES = 1
INTERCHANGES WITH ZERO SEPARATION TAPE 1 = 5 TAPE 2 = 7

PURPOSE 1

SEPARATION GRP V1	NEGATIVE -50 TO -31	-30 TO -21	-20 TO -11	-10 TO -8	-7 TO -6	-5 TO -4	-3 TO -3	-2 TO -2	-1 TO -1	-0 TO +0	POSITIVE +1 TO +1	+2 TO +2	+3 TO +3	+4 TO +5	+6 TO +7	+8 TO +10	+11 TO +20	+21 TO +30	+31 TO +50	TOT
0- 100	144	0	0	0	0	0	0	0	0	221	0	0	0	0	0	0	0	0	314	679
101- 200	4	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	22	34
201- 300	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	9
301- 400	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3	5
401- 500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
TOTAL	149	0	0	0	0	0	0	0	0	231	0	0	0	0	0	0	0	0	349	729

UAG - URBAN/SYS
TRANPLAN SYSTEM
VERSION 7.0

MATRIX COMPARE OF HIGHWAY O/D TABLES
(BASE CASE VS TEST CASE 3)

DATE 07JAN92
TIME 14:36:45

VOLUME COMPARISON REPORT ---- STATISTICAL CALCULATIONS.

MAXIMUM CENTROID NUMBER = 27 NUMBER OF PURPOSES = 1

PURPOSE 1

VOLUME GRP V1	VOL. TAPE1	AVG. VOL.	VOL. TAPE2	AVG. VOL.	AVG. DIFF.	STD. DEV.	PRCNT S.D.	PRCNT TOTAL	WGHTD AVG.	ROOT MN SQ.	PRCNT RMS	SUM OF SQ DIFF
0- 100	14755	21.7	15042	22.2	-.42	2.46	.11	60.59	6.86	2.5	11.48	4229.
101- 200	4735	139.3	4706	138.4	.85	12.03	.09	19.44	1.68	12.1	8.66	4943.
201- 300	2120	235.6	2156	239.6	-4.00	6.20	.03	8.70	.23	7.4	3.13	490.
301- 400	1795	359.0	1803	360.6	-1.60	1.50	.00	7.37	.03	2.2	.61	24.
401- 500	949	474.5	953	476.5	-2.00	3.00	.01	3.90	.02	3.6	.76	26.
TOTAL	24354	33.4	24660	33.8	-.42	3.63	.11	100.00	10.85	3.6	10.93	9712.

TRIP END COMPARISON REPORT -- PURPOSE 1

	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS
TAPE 1	1	1762	3191	4953	0	11	990	516	1506	54
TAPE 2		1789	3258	5047	0		997	511	1508	60
DIFF		-27	-67	-94	0		-7	5	-2	-6
RATIO		1.02	1.02	1.02	.00		1.01	.99	1.00	1.11
TAPE 1	2	1711	2827	4538	399	12	1332	707	2039	120
TAPE 2		1725	2869	4594	403		1368	718	2086	120
DIFF		-14	-42	-56	-4		-36	-11	-47	0
RATIO		1.01	1.01	1.01	1.01		1.03	1.02	1.02	1.00
TAPE 1	3	1736	1772	3508	492	13	940	501	1441	75
TAPE 2		1753	1793	3546	497		983	531	1514	76
DIFF		-17	-21	-38	-5		-43	-30	-73	-1
RATIO		1.01	1.01	1.01	1.01		1.05	1.06	1.05	1.01
TAPE 1	4	1569	1896	3465	457	14	236	474	710	12
TAPE 2		1583	1929	3512	456		238	477	715	12
DIFF		-14	-33	-47	1		-2	-3	-5	0
RATIO		1.01	1.02	1.01	1.00		1.01	1.01	1.01	1.00
TAPE 1	5	701	400	1101	31	15	749	414	1163	68
TAPE 2		699	389	1088	31		780	421	1201	66
DIFF		2	11	13	0		-31	-7	-38	2
RATIO		1.00	.97	.99	1.00		1.04	1.02	1.03	.97
TAPE 1	6	656	356	1012	34	16	1045	715	1760	161
TAPE 2		661	370	1031	33		1063	725	1788	164
DIFF		-5	-14	-19	1		-18	-10	-28	-3
RATIO		1.01	1.04	1.02	.97		1.02	1.01	1.02	1.02
TAPE 1	7	617	624	1241	81	17	336	169	505	10
TAPE 2		617	621	1238	80		349	175	524	10
DIFF		0	3	3	1		-13	-6	-19	0
RATIO		1.00	1.00	1.00	.99		1.04	1.04	1.04	1.00
TAPE 1	8	144	345	489	0	18	354	714	1068	24
TAPE 2		142	340	482	0		355	718	1073	22
DIFF		2	5	7	0		-1	-4	-5	2
RATIO		.99	.99	.99	.00		1.00	1.01	1.00	.92
TAPE 1	9	1133	700	1833	101	19	452	243	695	22
TAPE 2		1149	719	1868	101		454	245	699	21
DIFF		-16	-19	-35	0		-2	-2	-4	1
RATIO		1.01	1.03	1.02	1.00		1.00	1.01	1.01	.95
TAPE 1	10	1280	996	2276	244	20	942	778	1720	180
TAPE 2		1284	1001	2285	241		973	783	1756	180
DIFF		-4	-5	-9	3		-31	-5	-36	0
RATIO		1.00	1.01	1.00	.99		1.03	1.01	1.02	1.00

TRIP END COMPARISON REPORT -- PURPOSE 1

	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS
TAPE 1	21	470	244	714	18					
TAPE 2		473	250	723	19					
DIFF		-3	-6	-9	-1					
RATIO		1.01	1.02	1.01	1.06					
TAPE 1	22	1149	1433	2582	362					
TAPE 2		1159	1448	2607	362					
DIFF		-10	-15	-25	0					
RATIO		1.01	1.01	1.01	1.00					
TAPE 1	23	349	705	1054	21					
TAPE 2		354	722	1076	21					
DIFF		-5	-17	-22	0					
RATIO		1.01	1.02	1.02	1.00					
TAPE 1	24	674	357	1031	36					
TAPE 2		679	351	1030	36					
DIFF		-5	6	1	0					
RATIO		1.01	.98	1.00	1.00					
TAPE 1	25	472	958	1430	27					
TAPE 2		480	976	1456	27					
DIFF		-8	-18	-26	0					
RATIO		1.02	1.02	1.02	1.00					
TAPE 1	26	1469	1262	2731	99					
TAPE 2		1468	1264	2732	98					
DIFF		1	-2	-1	1					
RATIO		1.00	1.00	1.00	.99					
TAPE 1	27	1086	1057	2143	68					
TAPE 2		1085	1056	2141	67					
DIFF		1	1	2	1					
RATIO		1.00	1.00	1.00	.99					
TAPE 1	TOTALS	24354	24354	48708	3196					

TAPE 2	24660	24660	49320	3203
DIFF	-306	-306	-612	-7
RATIO	1.01	1.01	1.01	1.00

```
$REPORT MATRIX COMPARISON
$FILES
        INPUT FILE = MATCOM 1, USER ID = $HTRIPS.A1$
        INPUT FILE = MATCOM 2, USER ID = $HTRIPS.A3$
$HEADERS
        MATRIX COMPARE OF HIGHWAY O/D TABLES
        (BASE CASE VS TEST CASE 3)
$OPTIONS
        PRINT FREQUENCY DISTRIBUTION
        PRINT ZONAL DIFFERENCES
        PRINT TRIP END COMPARISON
        PRINT STATISTICAL SUMMARY
$PARAMETERS
$END TP FUNCTION
```

INPUT FILE NAME ---------- MATCON1

FILE CHARACTERISTICS

USER FILE IDENTIFICATION - HTRIPS.A1

FILE HEADER -------------   COMBINE HIGHWAY P/A AND A/P TABLES TO O/D FORMAT - ALT 1

GENERATING FUNCTION ------ MATRIX MANIPULATE

TYPE OF FILE ------------ VOLUME

GENERATION FILE NAME ----- TMAN3

GENERATION DATE ---------- 19DEC91   CURRENT DATE ---------- 07JAN92

GENERATION TIME ---------- 15:09:52   CURRENT TIME ---------- 14:36:45

FILE SIZE ---------------- MAXIMUM ZONE   =   27

MAXIMUM TABLE NO. =   1

INPUT FILE NAME ---------- MATCON2

FILE CHARACTERISTICS

USER FILE IDENTIFICATION - HTRIPS.A3

FILE HEADER -------------   COMBINE HIGHWAY P/A AND A/P TABLES TO O/D FORMAT - ALT 3

GENERATING FUNCTION ------ MATRIX MANIPULATE

TYPE OF FILE ------------ VOLUME

GENERATION FILE NAME ----- TMAN3

GENERATION DATE ---------- 02JAN92   CURRENT DATE ---------- 07JAN92

GENERATION TIME ---------- 15:48:15   CURRENT TIME ---------- 14:36:45

FILE SIZE ---------------- MAXIMUM ZONE   =   27

MAXIMUM TABLE NO. =   1

Transit Network

J0310 92004

```
XX      XX  XXXXXXXXX   XXXXXXXXX     XXXXXX    XX      XX          XX   XXXXXXXX   XX      XX   XXXXXXXX
XX      XX  XXXXXXXXXX  XXXXXXXXXX   XXXXXXXX   XXX     XX         XX   XXXXXXXXXX   XX    XX   XXXXXXXXXX
XX      XX  XX      XX  XX      XX  XX      XX  XXXX    XX        XX    XX      XX    XX  XX    XX      XX
XX      XX  XX      XX  XX      XX  XX      XX  XX XX   XX       XX     XX            XX  XX    XX
XX      XX  XXXXXXXXXX  XXXXXXXXXX  XXXXXXXXXX  XX  XX  XX      XX      XXXXXXXXX      XXXX     XXXXXXXXX
XX      XX  XXXXXXXXX   XXXXXXXXXX  XXXXXXXXXX  XX  XX  XX     XX        XXXXXXXXX      XX       XXXXXXXXX
XX      XX  XX  XX      XX      XX  XX      XX  XX   XX XX    XX                XX      XX              XX
XX      XX  XX   XX     XX      XX  XX      XX  XX    XXXX   XX         XX      XX      XX      XX      XX
XXXXXXXXXX  XX    XX    XXXXXXXXXX  XX      XX  XX     XXX  XX          XXXXXXXXXX      XX      XXXXXXXXXX
 XXXXXXXX   XX     XX   XXXXXXXXX   XX      XX  XX      XX XX            XXXXXXXX       XX       XXXXXXXX

XXXXXXXXXX  XXXXXXXXX    XXXXXXXX   XX      XX  XXXXXXXXX   XX           XXXXXXXX   XX      XX
XXXXXXXXXX  XXXXXXXXXX  XXXXXXXXXX  XXX     XX  XXXXXXXXXX  XX          XXXXXXXXXX  XXX     XX
    XX      XX      XX  XX      XX  XXXX    XX  XX      XX  XX          XX      XX  XXXX    XX
    XX      XX      XX  XX      XX  XX XX   XX  XX      XX  XX          XX      XX  XX XX   XX
    XX      XXXXXXXXXX  XX      XX  XX  XX  XX  XXXXXXXXXX  XX          XX      XX  XX  XX  XX
    XX      XXXXXXXXX   XXXXXXXXXX  XX  XX  XX  XXXXXXXXX   XX          XXXXXXXXXX  XX  XX  XX
    XX      XX  XX      XXXXXXXXXX  XX   XX XX  XX          XX          XXXXXXXXXX  XX   XX XX
    XX      XX   XX     XX      XX  XX    XXXX  XX          XX          XX      XX  XX    XXXX
    XX      XX    XX    XX      XX  XX     XXX  XX          XXXXXXXXXX  XX      XX  XX     XXX
    XX      XX     XX   XX      XX  XX      XX  XX          XXXXXXXXXX  XX      XX  XX      XX
```

```
*************************************************************************************
*                                                                                   *
*                             MATRIX COMPARSION REPORTS                             *
*                                                                                   *
*          MATRIX COMPARE OF TRANSIT O/D TABLES                                     *
*          (BASE CASE VS TEST CASE 3)                                               *
*                                                                                   *
*************************************************************************************
```

FILE CHARACTERISTICS

USER FILE IDENTIFICATION - TTRIPS.A3

FILE HEADER --------------   MATRIX COMPARE OF TRANSIT O/D TABLES
(BASE CASE VS TEST CASE 3)

GENERATING FUNCTION ------ MATRIX MANIPULATE

TYPE OF FILE ------------- VOLUME

GENERATION FILE NAME ----- TMAN3

GENERATION DATE ---------- 02JAN92   CURRENT DATE ---------- 07JAN92

GENERATION TIME ---------- 16:36:36   CURRENT TIME ---------- 14:37:58

FILE SIZE ---------------- MAXIMUM ZONE = 27

MAXIMUM TABLE NO. = 1

UAG - URBAN/SYS
TRANPLAN SYSTEM
VERSION 7.0

MATRIX COMPARE OF TRANSIT O/D TABLES
(BASE CASE VS TEST CASE 3)

PAGE NO. 1
DATE 07JAN92
TIME 14:37:58

VOLUME COMPARISON REPORT ---- VOLUME DIFFERENCES AND RATIOS.

MAXIMUM CENTROID NUMBER = 27 NUMBER OF PURPOSES = 1

ORIGIN ZONE 1 PURPOSE 1

	ZONE	1	2	3	4	5	6	7	8	9	0
TAPE 1	1	0	245	49	35	107	98	9	1	28	13
TAPE 2		0	247	46	33	107	102	9	1	25	14
DIFF.		0	-2	3	2	0	-4	0	0	3	-1
RATIO		.00	1.01	.94	.94	1.00	1.04	1.00	1.00	.89	1.08
TAPE 1	11	12	22	16	1	13	16	5	2	3	12
TAPE 2		13	16	8	2	6	13	2	3	3	7
DIFF.		-1	6	8	-1	7	3	3	-1	0	5
RATIO		1.08	.73	.50	2.00	.46	.81	.40	1.50	1.00	.58
TAPE 1	21	7	12	4	11	8	13	12			
TAPE 2		7	10	3	10	8	15	9			
DIFF.		0	2	1	1	0	-2	3			
RATIO		1.00	.83	.75	.91	1.00	1.15	.75			

SEPARATION COMPARISON REPORT ---- FREQUENCY DISTRIBUTION (V1-V2).

MAXIMUM CENTROID NUMBER = 27 NUMBER OF PURPOSES = 1

INTERCHANGES WITH ZERO SEPARATION TAPE 1 = 100 TAPE 2 = 99

PURPOSE 1

SEPARATION GRP	NEGATIVE										POSITIVE									
V1	-50 TO -31	-30 TO -21	-20 TO -11	-10 TO -8	-7 TO -6	-5 TO -4	-3 TO -3	-2 TO -2	-1 TO -1	-0 TO +0	+1 TO +1	+2 TO +2	+3 TO +3	+4 TO +5	+6 TO +7	+8 TO +10	+11 TO +20	+21 TO +30	+31 TO +50	TOT
0- 100	133	0	0	0	0	0	0	0	0	254	0	0	0	0	0	0	0	0	327	714
101- 200	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3	7
201- 300	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	7
301- 400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
TOTAL	135	0	0	0	0	0	0	0	0	257	0	0	0	0	0	0	0	0	337	729

VOLUME COMPARISON REPORT ---- STATISTICAL CALCULATIONS.

MAXIMUM CENTROID NUMBER = 27 NUMBER OF PURPOSES = 1

PURPOSE 1

VOLUME GRP V1	VOL. TAPE1	AVG. VOL.	VOL. TAPE2	AVG. VOL.	AVG. DIFF.	STD. DEV.	PRCNT S.D.	PRCNT TOTAL	WGHTD AVG.	ROOT MN SQ.	PRCNT RMS	SUM OF SQ DIFF
0- 100	5199	7.3	4818	6.7	.53	2.13	.29	63.96	18.70	2.2	30.14	3439.
101- 200	876	125.1	876	125.1	.00	1.20	.01	10.78	.10	1.2	.96	10.
201- 300	1740	248.6	1753	250.4	-1.86	1.64	.01	21.41	.14	2.5	1.00	43.
301- 400	313	313.0	315	315.0	-2.00	.00	.00	3.85	.00	2.0	.64	4.
TOTAL	8128	11.1	7762	10.6	.50	2.13	.19	100.00	19.12	2.2	19.64	3496.

TRIP END COMPARISON REPORT -- PURPOSE 1

	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS
TAPE 1	1	754	1379	2133	0	11	258	144	402	26
TAPE 2		719	1294	2013	0		260	152	412	28
DIFF		35	85	120	0		-2	-8	-10	-2
RATIO		.95	.94	.94	.00		1.01	1.06	1.02	1.08
TAPE 1	2	869	1253	2122	313	12	385	229	614	67
TAPE 2		846	1199	2045	315		343	202	545	64
DIFF		23	54	77	-2		42	27	69	3
RATIO		.97	.96	.96	1.01		.89	.88	.89	.96
TAPE 1	3	711	673	1384	290	13	236	129	365	40
TAPE 2		690	642	1332	291		187	113	300	39
DIFF		21	31	52	-1		49	16	65	1
RATIO		.97	.95	.96	1.00		.79	.88	.82	.98
TAPE 1	4	627	710	1337	269	14	58	117	175	6
TAPE 2		616	676	1292	268		56	114	170	6
DIFF		11	34	45	1		2	3	5	0
RATIO		.98	.95	.97	1.00		.97	.97	.97	1.00
TAPE 1	5	351	175	526	16	15	200	114	314	33
TAPE 2		352	181	533	16		163	90	253	33
DIFF		-1	-6	-7	0		37	24	61	0
RATIO		1.00	1.03	1.01	1.00		.81	.79	.81	1.00
TAPE 1	6	352	168	520	18	16	382	252	634	91
TAPE 2		347	169	516	16		360	246	606	92
DIFF		5	-1	4	2		22	6	28	-1
RATIO		.99	1.01	.99	.89		.94	.98	.96	1.01
TAPE 1	7	268	216	484	49	17	88	46	134	6
TAPE 2		266	204	470	46		69	36	105	5
DIFF		2	12	14	3		19	10	29	1
RATIO		.99	.94	.97	.94		.78	.78	.78	.83
TAPE 1	8	19	45	64	0	18	79	163	242	11
TAPE 2		19	44	63	0		79	161	240	12
DIFF		0	1	1	0		0	2	2	-1
RATIO		1.00	.98	.98	.00		1.00	.99	.99	1.09
TAPE 1	9	334	199	533	56	19	117	65	182	10
TAPE 2		316	187	503	56		113	62	175	10
DIFF		18	12	30	0		4	3	7	0
RATIO		.95	.94	.94	1.00		.97	.95	.96	1.00
TAPE 1	10	348	286	634	140	20	282	234	516	104
TAPE 2		346	298	644	138		243	216	459	103
DIFF		2	-12	-10	2		39	18	57	1
RATIO		.99	1.04	1.02	.99		.86	.92	.89	.99

TRIP END COMPARISON REPORT -- PURPOSE 1

	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS	ZONE/DIST	ORIG/PROD	DEST/ATTR	TOTAL	INTRATRIPS
TAPE 1	21	164	81	245	11					
TAPE 2		158	83	241	11					
DIFF		6	-2	4	0					
RATIO		.96	1.02	.98	1.00					
TAPE 1	22	450	555	1005	209					
TAPE 2		438	541	979	214					
DIFF		12	14	26	-5					
RATIO		.97	.97	.97	1.02					
TAPE 1	23	86	171	257	10					
TAPE 2		83	162	245	10					
DIFF		3	9	12	0					
RATIO		.97	.95	.95	1.00					
TAPE 1	24	171	98	269	19					
TAPE 2		167	95	262	21					
DIFF		4	3	7	-2					
RATIO		.98	.97	.97	1.11					
TAPE 1	25	103	216	319	14					
TAPE 2		93	183	276	14					
DIFF		10	33	43	0					
RATIO		.90	.85	.87	1.00					
TAPE 1	26	243	210	453	55					
TAPE 2		243	218	461	56					
DIFF		0	-8	-8	-1					
RATIO		1.00	1.04	1.02	1.02					
TAPE 1	27	193	200	393	40					
TAPE 2		190	194	384	38					
DIFF		3	6	9	2					
RATIO		.98	.97	.98	.95					
		--------	--------	--------	--------					
TAPE 1	TOTALS	8128	8128	16256	1903					

TAPE 2	7762	7762	15524	1902
DIFF	366	366	732	1
RATIO	.95	.95	.95	1.00

```
$REPORT MATRIX COMPARISON
$FILES
        INPUT FILE = MATCOM 1, USER ID = $TTRIPS.A1$
        INPUT FILE = MATCOM 2, USER ID = $TTRIPS.A3$
$HEADERS
        MATRIX COMPARE OF TRANSIT O/D TABLES
        (BASE CASE VS TEST CASE 3)
$OPTIONS
        PRINT FREQUENCY DISTRIBUTION
        PRINT ZONAL DIFFERENCES
        PRINT TRIP END COMPARISON
        PRINT STATISTICAL SUMMARY
$PARAMETERS
$END TP FUNCTION
```

```
INPUT FILE NAME ---------- MATCOM1

   FILE CHARACTERISTICS
--------------------------

USER FILE IDENTIFICATION - TTRIPS.A1

FILE HEADER --------------    COMBINE TRANSIT P/A AND A/P TABLES TO O/D FORMAT - ALT 1


GENERATING FUNCTION ------ MATRIX MANIPULATE

TYPE OF FILE ------------- VOLUME

GENERATION FILE NAME ----- TMAN3

GENERATION DATE ---------- 19DEC91                        CURRENT DATE ----------  07JAN92

GENERATION TIME ---------- 15:10:55                       CURRENT TIME ---------- 14:37:58

FILE SIZE ---------------- MAXIMUM ZONE      =    27

                           MAXIMUM TABLE NO. =     1

INPUT FILE NAME ---------- MATCOM2

   FILE CHARACTERISTICS
--------------------------

USER FILE IDENTIFICATION - TTRIPS.A3

FILE HEADER --------------    COMBINE TRANSIT P/A AND A/P TABLES TO O/D FORMAT - ALT 3


GENERATING FUNCTION ------ MATRIX MANIPULATE

TYPE OF FILE ------------- VOLUME

GENERATION FILE NAME ----- TMAN3

GENERATION DATE ---------- 02JAN92                        CURRENT DATE ----------  07JAN92

GENERATION TIME ---------- 16:36:36                       CURRENT TIME ---------- 14:37:58

FILE SIZE ---------------- MAXIMUM ZONE      =    27

                           MAXIMUM TABLE NO. =     1
```

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO
EPA 452/R-93-003		

4. TITLE AND SUBTITLE Issues and Approaches to improving Transportation Modeling for Air Quality Analysis.	5. REPORT DATE January, 1993 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Air Quality Planning & Standards Environmental Protection Agency Research Triangle Pk., NC 27711	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68D00102
12. SPONSORING AGENCY NAME AND ADDRESS Director, Office of Air Quality Planning & Standards Office of Air & Radiation US EPA Research Triangle PK., NC 27711	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE 68A

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Several studies sponsored by the EPA, national organizations, and state and local agencies have been initiated to try to improve transportaion modeling. This report documents the results of one of these efforts. The purpose of this work was to produce a list of current shortcomings both in transportation model structure and in the ways transportation models are used, written in large part from the perspective of air quality modelers. The intention has been to provide a document which would be of use to both transportation and air quality modelers. In addition, a list of improvements to either the models or transportation modeling procedures, augmented by sample model runs demonstrating implementation of some of these suggestions, is provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Quality Analysis Air Quality Modeling Improving Transportation Modeling	Improving Transportation Modeling	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Unlimited	Unclassified	
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	