TECHNICAL REPORT

TRANSPORTATION AIR QUALITY CONFORMITY MODELING IN SACRAMENTO AND SAN JOAQUIN VALLEYS

DRAFT

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Request to summarize major elements of transportation-air quality modeling in Sacramento and the San Joaquin Valley

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1.0 Introduction

Transportation air quality conformity models and practices are constantly being refined to improve estimation and prediction of travel activity and vehicle emissions. However, there are still many hurdles to be overcome.

The first step towards improving the modeling process requires an understanding of the models that are used, and how they all work together. This paper traces some of the major links between the models used in conformity. We also conduct an in-depth review of the state-of-the-practice for the Sacramento and San Joaquin Valley regions. The general format roughly follows the actual conformity modeling process, beginning with the travel demand models, working through the emission models, post-processing practices, and finishing with emission budgets and the final conformity determinations.

1.1 Project Scope

This project focuses on the air quality conformity aspects of travel demand and emission modeling. Consequently, not all of the components and assumptions included in the travel and emissions models will be discussed. This report will highlight only those components, steps, methods, and formulas that have significant and direct impacts on the emission estimates used by the local agencies to demonstrate conformity.

The information contained in this report is accurate as of Spring 1999. Please note, however, that the San Joaquin Valley agencies are currently in the process of upgrading their travel model software from MINUTP to TP+/Viper. It is not within the scope of this paper to detail the specific impacts the new model might have on future modeling processes.

2.0 Data Collection

The data for this report were collected from agencies responsible for conducting conformity in the Sacramento and San Joaquin Valley regions. Contacts for each jurisdiction are as follows:

Agency	Acronym	Staff Contact
Sacramento Valley		
Sacramento Area Council of Governments	SACOG	Mr. Gordon Garry
San Joaquin Valley		
Council of Fresno County Governments	COFCG	Mr. Mike Bitner
Kern Council of Governments	Kern COG	Ms. Michelle Bitner
Kings County Association of Governments	KCAG	Mr. David Lear
Madera County Transportation Commission	MCTC	Mr. Bob Stone
Merced County Association of Governments	MCAG	Mr. Matt Fell
San Joaquin Council of Governments	SJCOG	Mr. Kim Kloeb
Stanislaus Area Association of Governments	SAAG	Mr. John Gedney
Tulare County Association of Governments	TCAG	Mr. Gary Mills

Initial data collection consisted of a survey (see Appendix A) developed with pre-testing and feedback from Gordon Garry at SACOG. This survey was designed to elicit specific information regarding travel and emission modeling practices related to regional air quality conformity determinations. We also requested copies of each region's most recent conformity determination. The survey was emailed to participating agencies in two waves.

After the first wave, we discovered that the survey was not providing the detail desired for this report. Specific travel model information such as speed congestion curves and detailed feedback processes were not adequately discussed in returned surveys. As a supplement to the survey, travel model update reports were requested from each agency.

In most cases, even the travel model update reports, which contain information on the development and calibration of the travel model, didn't provide the level of detail desired. In addition, since all of the model update reports were written by consultants, many of the agency staff members were not familiar with the detailed assumptions and equations embedded in the models. In spite of this limitation, the collected information provides a good overview of the state-of-the-practice in conformity modeling in the Sacramento and San Joaquin Valleys.

3.0 Travel and Emission Model Processes – Overview

The impetus for this report arises from the need to understand the relationship between the travel demand models and emission models used for air quality conformity. A thorough understanding is necessary before improvements in the modeling process can be suggested. Taken as a whole, the conformity modeling process is extremely complex. Each assumption influences the outcome, and many steps make important contributions. Key to understanding the process is understanding how vehicle miles traveled (VMT), trips, and network speed estimates tie together the travel demand and emission modeling processes. Figure 3.1 illustrates these steps, beginning with raw data, and ending with the regional motor vehicle emission estimates.

Figure 3.1 begins with the *network characteristics* of the travel demand model. Among the foundational information for the model, link capacities and free-flow speeds are established for all facility types in the modeling domain. Once the network has been created, the traditional "four-step process" is used to model regional travel behavior. The first step, *trip generation*, computes the zonal productions and attractions. *Trip distribution* then generates a trip matrix linking productions with attractions by zone, and incorporates friction factors that constrain trips based on the "time cost" of the trip. *Mode choice* determines the percentage of trips taken by vehicle, transit or other alternative forms of transportation. The final step, *trip assignment*, "loads" the trips from the trip matrix onto the network links using speed congestion curves. This results in, among other important information, trips on links (from which VMT can be computed), and congested link speeds. In some regions within the study area, a feedback loop is used to incorporate the congested speeds back into the trip distribution step.

Outputs from the travel demand model are considered part of the "activity data" inputs for the emission models. Emission models use activity data in conjunction with emission factors that are separately developed in EMFAC and technology travel fractions developed in WEIGHT to calculate emission rates. For ozone and PM_{10}, some post-processing of the emission estimates is necessary to account for emissions and emission benefits not already incorporated into the model.

All of the regions in the Sacramento and San Joaquin Valleys follow this general process, although some methodologies differ according to region-specific needs. In the following discussion of the modeling process illustrated in Figure 3.1, regional methodologies will be used as examples of the state-of-the-practice air quality conformity modeling process.

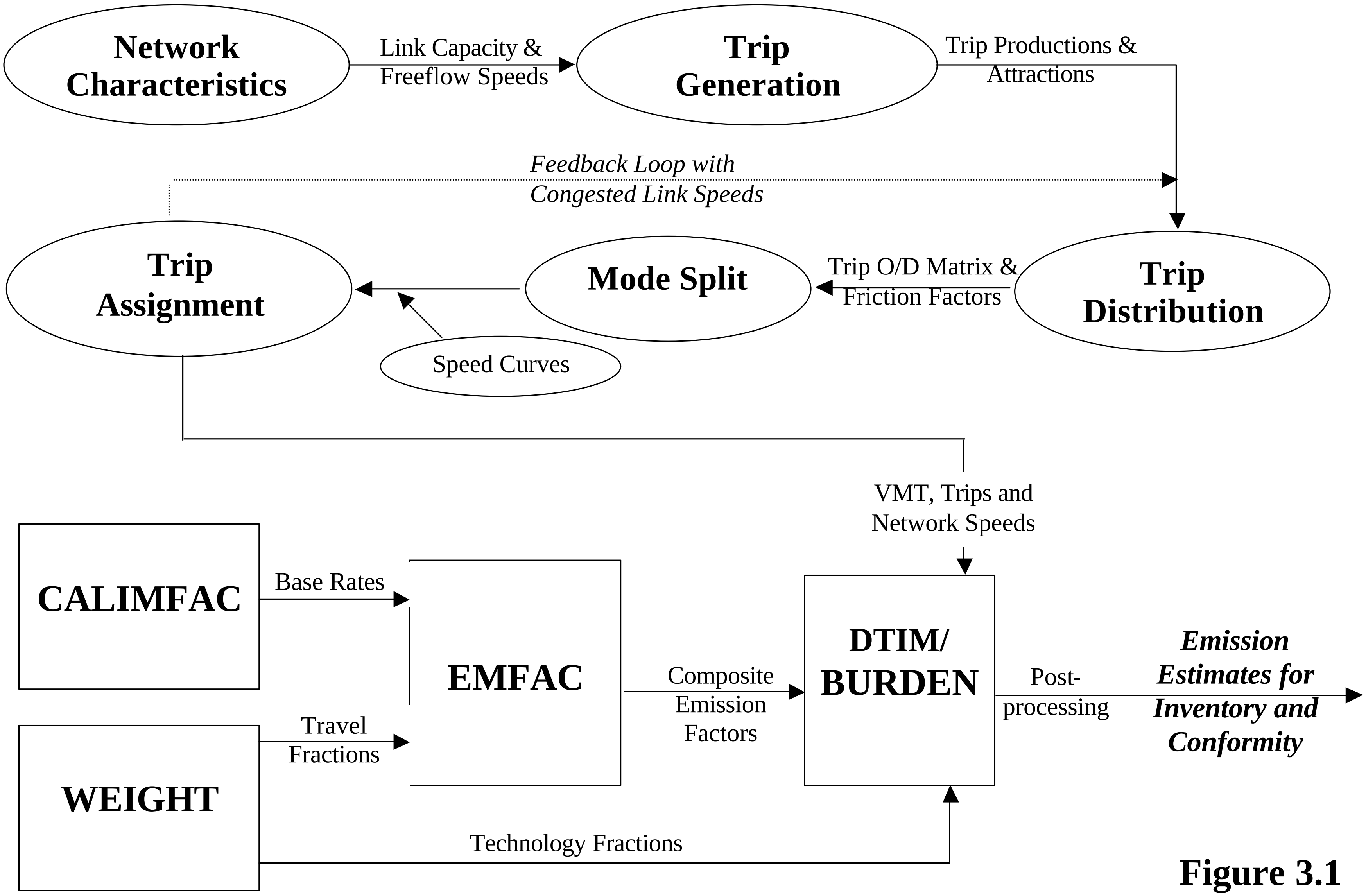

Figure 3.1

Travel Model and Emission Model Processes

(sources: ARB, 1996a and Ortúzar and Willumsen, 1995)

4.0 The Travel Demand Model

4.1 Network Characteristics

The zone structure and roadway network provide the foundation for the regional travel demand model. The zone structure is developed using socioeconomic data obtained from, among others: the US Census, the California Department of Finance (DOF), and regional surveys. The zones represent the disaggregation of the regions' various land use, social and demographic characteristics.

The roadway network is a representation of the physical roads in the region. It is constructed of road segment "links" that include: link distance, free-flow speed, and capacity. Link speeds and capacity are limited by the road classification assigned to that particular link. Depending on the level of detail needed in the model, more or less specific classifications may be used. Table 4.1 shows the road classifications and associated capacity and free-flow speed ranges for each region analyzed in this report

Free-flow speeds are generally obtained from posted speed limits and regional travel time surveys. The use of free-flow speed *ranges* in the road classifications rather than a single speed allows for the inclusion of roadway design constraints (tight curves, reduced, shoulder widths, etc.), which act to reduce the free-flow speeds on some links (SACOG, 1999a).

4.1.1 Regional Comparisons

There are a variety of road classifications currently applied in the Sacramento and Central Valley regions. The most common include:

- Freeways
- Expressways
- Arterials
- Collectors
- Freeway Ramps

Classifications can be further specified as "major" or "minor," as well as "urban," "rural" or "fringe."

Some regions include classifications unique to their area. Fresno County has a "state roads" classification, Merced County includes "city freeway ramps," and Tulare County has a "multilane highway" classification. These types of region-specific classifications do not affect the overall range of capacities and speeds covered from region to region, but rather provide specific detail valuable for that region. In other cases, as in Merced and Kings counties, classifications are necessary for adding greater network detail. The "local road" classification in these two counties allows a lower capacity of 350 v/l/h.

	Sacramento Valley Air Basin			*San Joaquin Valley Air Basin*								
	Sacramento County			**Fresno County**			**Kern County**			**Kings County**		
Road Classification	**Road Class.**	**v/l/h**	**mph**	**Road Class.**	**v/l/h**	**mph**	**Road Class.**	**v/l/h**	**mph**	**Road Class.**	**v/l/h**	**mph**
Freeway		2,000	55-65	U,R	2,000	55-75	U.R.F	1,750-2,000	65-75		2,000	INC
Highway											1,145-1,800	
Expressway		1,000	40-55	U	1,000	45-60	U	1,080	50-60		1,200	
State Road					800-100	40-65						
County Road											900-1,400	
Major Arterial		900	30-45	U,R	700-1,000	30-50	U,R,F	880-1,235	40-50		750	
Minor Arterial		800	30-40				U,R,F	640	30-40			
Collector		700	20-35	U,R	600-700	30-50	U,R,F	500	25-30		500	
Local Collector					600	20-40					350	
Freeway Ramp		1,500*	15-65		1,250-1,800	25-45					1,500	
City Fwy Ramp												
Walk		n/a	3									
Freeway HOV Lane		2,000	55-65									
Fwy Mixed/HOV Connector		1,800	55-65									
Sources:	*(DKS, 1994b; SACOG, 1999a)*			*(COFCG, 1999; DKS, 1995b)*			*(Kern COG, 1999; Baron-Aschman, 1996)*			*(Dowling Assoc., 1995)*		

	San Joaquin Valley Air Basin (con.)										
	Merced County			**San Joaquin County**			**Tulare County**			**SAAG**	**MCAG**
Road Classification	**Road Class.**	**v/l/h**	**mph**	**Road Class.**	**v/l/h**	**mph**	**Road Class.**	**v/l/h**	**mph**		
Freeway		2,000	55+		1850	55-65		2,000	INC	INC	INC
Highway								1,900			
Expressway		1,800	50+		900	50					
State Road					900	40-55		900			
County Road											
Major Arterial	R	900	45-55		750	30-50	U	800-900			
Minor Arterial		750	35-45								
Collector		500	25-35		600	25-35	U	600-700			
Local Collector		350	15-25								
Freeway Ramp		1,500	35					800			
City Fwy Ramp		500	35								
Walk											
Freeway HOV Lane					1850	55-65					
Fwy Mixed/HOV Connector					0	65					
Sources:	*(MCAG, 1999)*			*(DKS Assoc., 1994a)*			*(TCAG, 1999)*				

U=Urban, R=Rural, F=Fringe, INC=Incomplete Data

Table 4.1
Road Classifications, Capacity, and Speed Classes

4.1.2 Conformity Implications

The zone structure and roadway network influence the conformity process through land use and link characteristics. Land use influences are indirect, taking shape in the socioeconomic data used to develop the zonal structure. The largest land use impact is in the generation of productions and attractions within the region, which in turn determine where people are coming from and going to. These data are primarily functions of local land use decisions, development, and population projections.

Since conformity determinations project emissions into the future, travel models allow changes to be made in the roadway network, residential and commercial development, and socioeconomic trends by year of analysis. Out-year network changes influence the number of trips, vehicle miles traveled, and speeds. These in turn, influence the projected emission estimates.

Alternatively, link characteristics have a direct influence on the model through free-flow speed and capacity ranges. Free-flow link speeds and link capacities are used directly in volume-to-capacity (v/c) and congested link speed calculations. Link characteristics play vital roles in both the trip distribution and trip assignment steps.

4.2 Trip Generation

The first step in the traditional "four-step" modeling process is trip generation. Trip generation uses zone-specific socioeconomic data to determine, for each zone, the number of trips produced by and attracted to that zone. The generated trips are categorized into trip purposes (see Table 4.2), and sometimes classified by time of day. The resulting productions and attractions serve as inputs to the trip distribution step in which a trip matrix specifying origin/destination pairs between zones is created. Trips can also take place to and from areas outside the modeling domain. These trips, described as internal-external, external-internal (IXXI) and external-external (X-X), are not included in the trip generation process.

	Sacramento Valley Air Basin	*San Joaquin Valley Air Basin*						
Trip Purpose	**Sacramento**	**Fresno**	**Kern**	**Kings**	**Merced**	**Madera**	**SJC**	**Tulare**
Home to Work	X	X		X	X	X	X	X
H - W ($0 - $9,999)			X					
H - W ($10,000 - $19,999)			X					
H - W ($20,000 - $49,999)			X					
H - W ($50,000+)			X					
Home - Elem. School	X		X					
Home - High School			X					
Home- College/Univ.			X					
Home to Shopping	X	X	X	X	X	X	X	X
Home to Other	X	X	X	X	X	X	X	X
Non-home-based work to Other	X	X	X				X	X
Non-home-based other to Other	X	X	X	X	X	X	X	X
Heavy Duty Trucks			X*					
Internal-External/External-Internal			X	X	X	X	X	
External to External	X				X		X	
Commercial Vehicles	X*							

* Specific vehicle type and purpose identified in the model, INC=Incomplete Data

T

Trip Purposes by

(Sources: SACOG, 1999a; COFCG, 1999a; Kern COG, 1999; Dowling
MCAG, 1999; MCTC, 1999; DKS Assoc., 1994a; DKS

4.2.1 Regional Comparisons

The primary differences in the trip distribution among the counties in the study area are the trip purpose definitions. In general, travel models will include five basic trip purposes:

- Home to Work
- Home to Shopping
- Home to Other
- Work to Other (or Other to Work, or Non-home-based work to Other)
- Other to Other (or Non-home-based other to Other)

Depending on the socioeconomic characteristics of the region, more specific classifications may be necessary. In Kern County, trip purposes are broken down by income group as well as educational destinations. This greater level of detail provides more accurate trip distribution and mode choice results (Barton-Aschman Associates, Inc., 1996). Educational locations are modeled separately because they are unique attraction locations and have specific use characteristics (Barton-Aschman Associates, Inc., 1996). As illustrated in Table 4.2, other regions have chosen specific purposes to fit local needs as well, although none to the degree that Kern County has.

Trip purposes can also refer to specific types of vehicles. The Sacramento region travel model SACMET, and Kern County both specify a trip purpose for commercial truck activity. The trip purposes are "trucks" and "commercial vehicles," respectively (SACOG, 1999a; Kern COG, 1999). This special treatment is considered necessary to account for the amount of activity these vehicle types demonstrate on the road network.

All of the regions we contacted utilized trip tables developed by Caltrans from the Caltrans Statewide Travel Survey to estimate productions and attractions for IXXI and X-X trips. Since the Caltrans trip matrices also include origins and destinations, the trip distribution step for IXXI and X-X trips is unnecessary.

Calculation of the trip productions and attractions for external trips can be done a number of different ways. SACMET begins with gateway traffic count data from the model base year, and adjusts them based on Caltrans data (SACOG, 1999a). Kern County groups IXXI trips together, and assumes that both are external to internal trips with all trip attractions occurring at the internal zone. The trip attractions are then calculated based on Caltrans data (Barton-Aschman Associates, Inc., 1996).

In some areas, such as San Joaquin County, Merced County, Madera County, and Kings County, the travel model modeling domain incorporates adjacent regions outside of the local jurisdiction. This allows for more accurate estimations and facilitates cross-county coordination. In these cases, IXXI trips do not necessarily have a trip end in the county being analyzed for air quality conformity. To account for this, a percentage of the trips generated per zone are assigned as internal to external trips based on base year traffic count data from Caltrans.

4.2.2 Conformity Implications

Trip generation has an indirect, but substantial impact on the conformity process through the development of trip ends. Trip ends are critical for deriving link speeds, regional VMT, and total trips. In addition, the variety of trip purposes help determine when and where trips are made in the trip assignment step. They also dictate to a certain extent, the volume of congestion-causing cars on a particular link. Finally, the locations of trip producers and attractors dictate the modes of transportation that are available for the associated trips; they influence the possibility or impossibility of trip taken on an alternative mode such as bus transit or light rail.

The impact of trip generation is clearly indirect, but it provides the information necessary for the calculation of the activity data that is eventually used in the emission models.

4.3 Trip Distribution

The trip distribution step combines the productions and attractions from trip generation into origin-destination pairs. Whereas in trip generation, each zone "generated" a certain number of trips, trip distribution "distributes" those trips between zones based on the shortest time path on the network using free-flow link speeds (Ortúzar and Willumsen, 1995). As mentioned earlier, the output of the trip distribution step is a trip matrix specifying zone-to-zone trip making activity (see Table 4.3).

	Attractions					
Generations	1	2	3	…j	…z	$Sum_{(j)}\ T_{ij}$
1	T_{11}	T_{12}	T_{13}	$…T_{1j}$	$…T_{1z}$	O_1
2	T_{21}	T_{22}	T_{23}	$…T_{2j}$	$…T_{2z}$	O_2
3	T_{31}	T_{32}	T_{33}	$…T_{3j}$	$…T_{3z}$	O_3
…i	T_{i1}	T_{i2}	T_{i3}	$…T_{ij}$	$…T_{iz}$	O_I
…z	T_{z1}	T_{z2}	T_{z3}	$…T_{zj}$	$…T_{zz}$	O_z
$Sum_{(i)}\ T_{ij}$	D_1	D_2	D_3	$…D_j$	$…D_z$	$Sum_{(ij)}T_{ij} = T$

T = number of trips between origin i and destination j
O = total number of trips originating in zone i
D = total number of trips attracted to zone j

Table 4.3
General Form of a Two-Dimensional Trip Matrix
(source: Ortúzar and Willumsen, 1995, p.152)

It is important to note that the trip matrix exists only on the *zonal* level. Although free-flow *link* speeds are used to calculate the shortest time path on the network, the trip matrix itself does not specify individual trip routes or congested speeds (Ortúzar and Willumsen, 1995). Link-level route assignment is done in the trip assignment step.

All of the regions studied in this report follow the gravity theory for trip distribution. The gravity model is described by DKS Associates (1994a, p. 55, 1995, p. 19, & 1996, p. 20) as follows:

> "The gravity model follows the concept of Isaac Newton's Universal Law of Gravitation, which states that the attractive force between two bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them. Similarly, zone-to-zone trip interchanges in the gravity model are directly proportional to the relative attraction or opportunity provided by each of the zones (productions and attractions) and inversely proportional to the spatial separation [in terms of time] between zones. Expressed mathematically, the gravity model formula of trip distribution is:
>
> $$T_{ij} = \frac{P_i\, A_j\, F(t_{ij})\, K_{ij}}{\Sigma_{x=1\ldots n}\, [A_x\, F(t_{ij})\, K_{ij}]}$$
>
> where:
>
> T_{ij} = number of trips produced in zone i and attracted to zone j
> P_i = total number of trips produced in zone i
> A_j = attractions of zone j
> t_{ij} = travel time in minutes between zone i and zone j
> $F(t_{ij})$ = the friction factors between zone i and zone j
> K_{ij} = zone-to-zone adjustment factor (K-factor)
> n = number of zones
>
> The inputs to the gravity model include the person trip productions and attractions for each zone, the zone-to-zone travel times, and friction factors which define the effects of travel time. The zone-to-zone distributions are calculated separately for each trip purpose."

Of particular interest for this report are the variables "t_{ij}," "$F(t_{ij})$," and "K_{ij}" because they are related to vehicle speeds on the network. The travel times between zones, t_{ij}, are calculated using link distances and free-flow speeds, and defined as the shortest time path between zones "i" and "j" (Ortúzar and Willumsen, 1995).

Friction factors, "$F(t_{ij})$," determine the "attractiveness" of zones based on their spatial separation and serve as constraints to trip-making between zones. Conceptually, as the distance (measured by travel time) between two zones increases, the attractiveness of travel between those zones decreases (Barton-Aschman Associates, 1996). Friction factors generally correspond to *specific trip purposes*, accounting for the possibility that people will drive further for work purposes than for school or shopping trips (DKS Associates, 1994a). The larger the friction factor, the larger the multiplier becomes, increasing the number of trips that are attracted from zone i to zone j.

The final variable of interest is the K-factor, "K_{ij}." K-factors are used to adjust the trip distribution equation when the estimated trips do not match observed trips very well (DKS Associates, 1994a). In some regions, K-factors are used for all trip purposes, while in others, they are used only in specific instances. Ortúzar and Willumsen (1995, p. 182) caution against using a model with a full set of K-factors, arguing that their use might only be justified in areas that have "a small number of zone pairs…with a special trip-making association which is likely to remain in the future…"

4.3.1 Regional Comparisons

The trip distribution processes used throughout the Sacramento and San Joaquin Valleys are similar across counties. The only differences are in the *friction factors* that are used in the equations, the location-specific *K-factors*, and whether or not the region has a *feedback loop*. All counties use friction factors, but each set is tailored to local conditions. Friction factors are sometimes borrowed from neighboring counties and adjusted for differences in trip length patterns. This is the case for the Fresno and Tulare County models, whose friction factors are based on those developed in Sacramento for the 94.0 version of the SACMET Regional Travel Demand Model.

The friction factors in SACMET 94.0 were updated in SACMET version 95.0 as noted in the SACOG memorandum dated April 30, 1996. In general, home-based work friction factors were adjusted to make shorter trips more attractive, while non-work trip purposes were adjusted to reduce the number of very short trips. The initial SACMET 94.0 friction factors were developed from calibration procedures using travel times from a previous (but not final) model, as well as additional overriding adjustments made to improve the comparison of modeled traffic volumes to observed counts. The adjustments made in SACMET 94.0 include (DKS Associates, 1994b, p. 7-3):

- "a 'steepening' of the curves for short trip lengths (below 15 minutes), for home-based shop, other, work-other, and other-other, in conjunction with an increase in trip generation in those purposes (by about 20 percent), to add more short trips into the model…

- Steepening of the curves for longer trip lengths (most significantly above about 30 minutes) of home-based other, work-other, and other-other trips, in response to high modeled traffic volumes on many freeways. License to adjust long trips this way was deemed acceptable and necessary, considering that the calibration of the curves is highly influenced by a small sample size of long trips (especially above 50 minutes), some of which might have been coding errors or commercial vehicle trips."

Both the Fresno County and Tulare County travel models used the SACMET 94.0 friction factors as a starting point. After the models were run, the resulting trip lengths were compared to the trip lengths reported in the Caltrans travel survey for Fresno and Tulare counties, respectively. Based on the analyses, the original friction factors were adjusted to reflect the differences in region-specific trip length patterns. In Fresno County, four rounds of adjustment were needed to calibrate the model estimates with survey trip lengths, while Tulare County needed five rounds. Appendix B contains sample graphs and tables illustrating the friction factors in SACMET 94.0, the Fresno model, and the Tulare travel demand model.

Most of the regions also use K-factors. The San Joaquin County travel model only uses them to adjust for home-to-work trip purposes, while the Kern, Fresno and Tulare models need them to adjust over-estimated trip lengths for all trip purposes in rural areas. K-factor values are inputs into the gravity model, as illustrated by the gravity equation above.

In Fresno County, for example, the model over-estimated two types of trip combinations: trips between rural areas and Fresno/Clovis, and trips between the northern and southern parts of the Fresno urban area (DKS Associates, 1995). Analysis of Fresno travel survey data showed that households in the rural areas did most of their trip-making within their town or immediate vicinity. To adjust for this observed behavior, each traffic analysis zone (TAZ) was identified as either large urban, small urban, or rural. For the small urban and rural zones, factors were used to adjust trip lengths to those observed in the Caltrans survey data, and an overall K-factor of 0.05 was applied for estimating trip distribution between rural and urban areas. For the northern vs. southern trips, it was observed that households in southern areas tended to make most of their trips within the southern area. A K-factor of 0.5 was applied for travel between the northern and southern urban areas, defined as areas north and south of McKinley Avenue (DKS Associates, 1995).

In Kern County, K-factors are applied to all trip purposes, and "were determined by trial and error with the main criterion for determining the K-factors being the match between modeled and observed traffic volumes on roadways entering the Bakersfield area." (Barton-Aschman Associates, Inc., 1996, p. 3-58) Five K-factor districts were established from the TAZs: Bakersfield, Northwest Kern, Northeast Kern, Southeast Kern, and Southwest Kern. Table 4.4 below illustrates the K-factors that are applied to trips travelling within and between districts.

District From	District To				
	Bakersfield	NW Kern	NE Kern	SE Kern	SW Kern
Bakersfield	2.0	1.0	0.5	0.5	0.5
NW Kern	1.0	2.0	0.5	0.1	0.5
NE Kern	0.5	035	4.0	0.1	0.1
SE Kern	0.5	0.1	0.1	4.0	0.1
SW Kern	0.5	0.5	0.1	0.1	2.0

Table 4.4
Trip Distribution K-Factors
(Source: Barton-Aschman Associates, Inc., 1996)

As discussed in the following section, the most important part of trip distribution for conformity is the reasonableness of travel times used to develop the initial trip matrix, assuming no feedback. Depending on local traffic conditions and the trip assignment methodology, a feedback loop may or may not be used. If a feedback loop is used, it will impact trip distribution by using congested speeds to calculate the values in the trip matrix rather than the uncongested speeds used in the initial run.

4.3.2 Conformity Implications

The primary conformity implication of the trip distribution step is the influence of travel time on the development of the trip matrix. Initial travel time estimates between zones are calculated from the shortest time path along the roadway network using free-flow conditions. In congested regions, the use of free-flow speeds as an estimate of congested network conditions tends to overestimate the number of long distance trips (DKS Associates, 1994a, 1995, 1996). To address this problem, feedback loops are used to redistribute trips through trip distribution using congested link speeds derived from trip assignment. The feedback loops used in the regions studied are described in detail in Section 4.6 below.

It should be noted that feedback loops are not necessary in all regions. Generally, they are utilized if a region suffers from either current or projected congestion on the roadway network. As described in Section 4.6, the use of feedback loops increases model processing times, often requiring several iterations before the final trip assignment is achieved.

4.4 Mode Choice

The mode choice step in the four-step process is considered by Ortúzar and Willumsen (1995, p. 187) to be the "single most important element in transport planning and policy making." In terms of air quality conformity, however, this step becomes important only if the region has *significant* amounts of travel in modes other than the personal motor vehicle. For most areas, the primary alternative mode is public transit, either as bus trips or demand response. The logic behind the use of alternative modes is that as more trips are taken using transit, less trips are thus taken in the car. This tradeoff will generally result in lower vehicle emissions. Since all of the counties in the study area have some form of transit, each regional travel demand model must account for the trips taken on transit. Many of the models assume the transit mode share to be a set percentage of the total trips in the region. The regions which follow this procedure include:

- Fresno County
- Kings County
- Merced County
- Madera County
- Stanislaus County
- Tulare County

The Fresno model assigns 0.5% of all trips in Fresno County to public transit. Since no major investments are planned that would significantly increase transit usage, this percentage stays constant for all planning years (DKS Associates, 1995). Similarly, Tulare County assigns 0.4% of all trips in the county to transit (DKS Associates, 1996). The model update reports for the remaining counties do not specify what percentage of transit trips are assumed in their models.

The remaining three regions in the study area, San Joaquin County, the Sacramento region, and Kern County have developed mode choice models to deal with trips generated from alternative modes of travel. San Joaquin County is somewhat of a special case. Although a mode choice model was developed, calibration difficulties have thus far prevented them from using it. The San Joaquin County mode choice model is described below for illustrative purposes, and is accompanied by a description of the procedure that was used to account for transit trips in the *1998 San Joaquin County Air Quality Conformity Determination*. Kern County and the SACMET mode choice models are also discussed.

4.4.1 San Joaquin County Mode Choice Model

San Joaquin County (SJC) currently has a mode choice model, but has not yet been used it due to calibration difficulties (SJCOG, 1998). As developed, the SJC mode choice model includes work and non-work mode choices. Adapted from the model used by SACOG, it has been refined to better address regional issues and take advantage of new data and modeling procedures (DKS Associates, 1994a, p. 59). Data sources for the model include:

- Stockton Metropolitan Transit District On-Board Survey,
- Transit ridership counts from the Stockton Metropolitan Transit District Comprehensive Operational Analysis,
- Auto occupancy from the Caltrans Statewide Travel Survey and San Francisco Bay Area surveys,
- Metropolitan Transportation Commission travel mode estimates that were used as a guide for adjustments.

The work trip mode choice model uses a *multinomial logit* formulation. Although this has been the most common model form for operational mode choice models (DKS Associates, 1994a), as described in the Kern County mode choice model section below, *nested logit* formulations are currently the state-of-the-art. The modes represented in the SJC model include:

- walk to transit
- drive to transit
- drive alone
- 2-person vehicle
- 3+ person vehicle

The non-work trip mode choice model is described by DKS Associates (DKS Associates, 1994a, p. 74) as follows:

> "Existing mode choice models for non-work travel do not exhibit any degree of consistency or similarity across cities, and the general level of credibility of these models is quite low. Consequently, it was not considered appropriate to attempt a transfer of non-work models from other areas to San Joaquin County. Instead, a factoring approach is used…similar to what has been done in Sacramento, Washington, D.C. and Atlanta. This method estimates non-work transit shares using factors that are applied to work transit shares estimated by the work mode choice model. The factors are applied for each zone-to-zone interchange that has transit service during the off-peak period. The factors are obtained from look-up tables that recognize the effects of auto ownership and trip distance on non-work transit shares. The non-work transit factors were originally derived from the

> Sacramento Area Council of Governments regional model and were adjusted during the mode choice validation process…
>
> …The factors represent the ratio between non-work transit mode share and home-based work mode share."

Since the San Joaquin County model did not use its mode choice model for the 1998 conformity determination, transit ridership was post-processed, and the total vehicle miles traveled on the roadway network reduced as described by the *1998 San Joaquin County Air Quality Conformity Assessment* (1998, p. 7):

> "Information on existing and future transit services was gathered from the local transit agencies and the San Joaquin Council of Governments *1998 Regional Transit Systems Plan Update*, which was approved by the Council of Governments Board on June 25, 1998. The *Regional Transit Systems Plan* represents a cooperative effort between Council of Governments staff and the local transit providers to determine future year transit service projections, and provides the most current transit information for San Joaquin County. All assumptions regarding transit service increases were taken from the *Regional Transit Systems Plan*. Average in-county trip length assumptions were broken down into three categories: local (10 miles), intercity (20 miles), and interregional (30 miles). Vanpool data for in-county trips were complied from San Joaquin Council of Governments' Commute Connection vanpool database and Vanpool Services Incorporated, a third party vanpool leasing company. An average van occupancy of 12 people was assumed, with a 10% annual growth rate applied for out-year projections. The growth rate was selected based on Vanpool Services Incorporated projections for vanpool expansion, with the recognition that vanpool participation can vary greatly depending on consumer perception or regulatory mandates."

Using this information, SJCOG staff calculated estimates of motor vehicle VMT reductions due to increased usage of transit for each model year. These reductions were offset by transit VMT additions due to the increased number of transit vehicles on the road. The VMT reductions and additions were applied to the VMT outputs from the travel model to obtain the final VMT estimates used in the emission models (SJCOG, 1998).

4.4.2 Kern Council of Governments Mode Choice Model

Kern County is one of the regions currently using a mode choice model for conformity purposes. In the Kern travel model, two mode choice model forms are used: home-based work, and non-work. Kern County's home-based work mode choice model took the mode choice model developed for Albuquerque, New Mexico and calibrated the model constants for the Bakersfield area. Albuquerque was chosen as the "donor" model because they share similar regional characteristics (Barton-Aschman Associates, Inc., 1996).

The home-based work mode choice model is a "state-of-the-art" nested logit mode choice model. Nested logit mode choice models are an improvement over multinomial logit models in that they recognize the potential for something other than equal competition among modes. Barton-Aschman Associates, Inc., present the standard logit formulation as follows:

$$P_i = \frac{e^{u_i}}{\sum_m e^{u_m}}$$

where:

P_i	= the probability of using mode i
U_i	= the utility of mode i
	= a linear combination of impedances and, possibly, socioeconomic and locational variables
	= $c_i + b_1x_{i1} + b_2x_{i2} + b_3x_{i3} + ...$
c_i	= constant for mode i
$b_1, b_2, b_3, ...$	= estimated model coefficients for variables 1, 2, 3, ...
$x_{i1}, x_{i2}, x_{i3}, ...$	= values for variables 1, 2, 3, ... for model

Nested logit model structures generally use multiple multinomial logit models. In a three tiered model, the first level is to determine between auto and transit, the second to choose between auto sub-modes, and the third to choose between transit sub-modes.

In Kern County, the structure is set up to allow the "shared ride" mode to compete equally with drive alone and transit at the first level. The implication of this, is that improvements to any of the three modes (drive alone, shared ride, and transit) will draw riders proportionately from the other two (Barton-Aschman Associates, Inc., 1996).

The model constants in logit-based models represent all attributes of the mode that have not been included in the mode's utility through the modeling process. Calibration of the constants was performed through iterative applications of the mode choice model using base year highway and transit networks and the modeled home-based work person trip tables (by income group). The constants were adjusted so that the modeled trips by sub-mode matched the observed trips from the 1995 transit on-board survey by sub-mode for each income group (Barton-Aschman Associates, Inc., 1996).

The calibrated model constants for the home-based work mode choice model are illustrated in Table 4.5.

Sub-mode	Low Income	Lower-Middle Income	Upper-Middle Income	High Income
Drive Alone	0	0	0	0
Shared Ride 2	-5.29382	-5.28034	-6.60175	-6.84048
Shared Ride 3	-7.40370	-7.38225	-8.00587	-8.90713

Shared Ride 4+	-10.26029	-10.23345	-9.71463	-10.21303
Walk to Local	-2.06557	-3.67933	-8.38208	-10.65257
Walk to Premium[2]	-6.77947	-8.04883	-13.13848	-15.08922
Drive to Formal Lot[2]	-8.74426	-8.61201	-12.9722	-9.5979
Drive to Informal Lot[2]	-4.92042	-6.45411	-9.5979	-12.9722

[1] Constants shown at lowest level of nesting structure
[2] Mode not available in base year.

Table 4.5
Calibrated Home-based Work Mode Choice Model Constants[1]
(source: Barton-Aschman Associates, Inc., 1996, p.3-97)

The model constants are applied at the lowest level of the nesting structure. For further detail, please reference Kern County's model methodology report (Barton-Aschman Associates, 1996).

Whereas Kern County's home-based work mode choice model was taken from Albuquerque, there was no such model available to develop the non-work model choice model. The non-work mode choice model was therefore based on "generally accepted principles and experience from regions that have estimated both work and non-work mode choice models." (Barton-Aschman Associates, Inc., 1996, p. 3-98) The principles are as follows:

Home-Based Non-Work Models:

- the in-vehicle time coefficient should be about one-third of the home-based work in-vehicle time coefficient,
- the implied value-of-time should be about 20 percent of the home-based work value-of-time,
- the out-of-vehicle time coefficient should be about 2.5 times the in-vehicle time coefficient,
- the first wait coefficient for wait times over 7.5 minutes should be about 40 percent of the out-of-vehicle time coefficient.

Non-Home-Based Models:

- the in-vehicle time coefficient should be about 1.25 times the home-based work in-vehicle time coefficient,
- the implied value-of-time should be about one-half of the home-based work value-of-time,
- the out-of-vehicle time coefficient should be about 2.5 times the in-vehicle time coefficient,
- the first wait coefficient for wait times over 7.5 minutes should be about 40 percent of the out-of-vehicle time coefficient.

These principles allowed the specification of coefficients for in-vehicle time, out-of-vehicle time, first wait time greater than 7.5 minutes, and cost. Because the non-work models were based on principles, simple binary choice models were used. Use of detailed nested logit or multinomial logit models was not reasonable. One exception was made for the home-based college/university trip purpose, which uses the home-based work model. This was allowed based on the premise that a college student's work is going to school. Table 4.6 illustrates the non-work mode choice model constants.

	Home-Based					Non-Home Based	
Constant	Elem/Middle School[1]	High School[1]	College/ University[2]	Shop[1]	Other[1]	Work-Other[1]	Other-Other[1]
Drive Alone	—	—	0	—	—	—	—
Shared Ride 2	—	—	-0.22757	—	—	—	—
Shared Ride 3	—	—	-1.01175	—	—	—	—
Shared Ride 4+	—	—	-1.53877	—	—	—	—
Walk to Local	—	—	-0.61957	—	—	—	—
Walk to Premium	—	—	-5.33347	—	—	—	—
Drive to Informal	—	—	-6.22498	—	—	—	—
Drive to Formal	—	—	-2.40114	—	—	—	—
Auto	0	0	—	0	0	0	0
Transit-Walk Access	-3.89306	-1.35581	—	-3.21017	-4.45564	-4.14265	-3.89007
Fringe Dummy (or Transit)	—	—	—	—	1.056	—	—

1 Constants are, in effect, at "top level" of nesting structure in the binary logit model.
2 Constants are for "bottom level" of nesting structure. Multiply the values by 0.35 for comparability to constants for un-nested models.

Table 4.6
Calibrated Non-Work Mode Choice Constants
(Source: Barton-Aschman Associates, Inc., 1996, p.3-102)

As noted above, please refer to Kern County's model methodology report for further details pertaining to the home-based work and non-work mode choice models.

4.4.3 SACMET Mode Choice Model

SACMET covers the second region currently utilizing a mode choice model for air quality conformity purposes. An important strength of SACMET is that it is based on a 1991 travel survey of about 4,000 households in the Sacramento region (DKS Associates, 1994b).

Within the full mode choice model, there are four independent logit models:

- Home-based work trips use a nested logit model
- Home-based shop and home-based other trips share a second home-based logit model
- Work-other and other-other trips share a non-home-based logit model
- Home-based school trips use a simple logit model.

The logit models includes the following modes:

- Drive alone
- HOV 2 (shared ride, 2 occupants)
- HOV 3+ (shared ride, 3 or more occupants)
- Drive to transit (park-and-ride)
- Walk to transit
- Walk
- Bike

During the development of the survey for this study, Gordon Garry noted that an important consideration in the mode choice model is the method used to account for the drive part of the drive access transit trips. In the SACOG model, the following procedure is used (SACOG, 1999a):

1) In the transit network skim, the park-and-ride lot used by a trip to access the transit system is flagged.
2) The nearest traffic analysis zone is then used as a proxy for that trip end.
3) The person trips are converted to vehicle trips for both the home-to-park-and-ride lot trip and for the return trip.
4) Finally, the vehicle trips are added to trip matrix for the appropriate time period.

4.4.4 Conformity Implications

The conformity implications of using a mode choice model can vary significantly. For regions *not* using mode choice models (those that include transit as a percentage of total trips), the incorporation of such models would enable them to more accurately represent the transit mode in their travel demand model. The more complex the mode choice model is in terms of stratifying trips across different modes, the greater the level of detail becomes.

Assuming the transit trip percentage is reasonably close to what is modeled using a simple mode choice model, the actual impact on modeled emissions may be negligible. Even if this were the case, the additional information provided by the mode choice model can be used to highlight areas for model improvement or even potential opportunities for regional programs promoting certain mode split goals. On the other hand, a more complex model which includes additional modes may demonstrate some emissions impact. For example in the Kern County mode choice model, there is a competitive distinction between the drive alone, shared ride, and transit trip modes. The choice of one mode diminishes equally from the other two. This layer of detail represents emission reductions due to ridesharing that would have otherwise not been captured in the analysis.

As far as federal regulations go, regardless of whether a mode choice model is used within a region or not, there must at least be a discussion of the impact of transit trips on the roadway network. The Conformity Rule specifically requires that the latest planning assumptions be used in developing the current and projected transit network, and that the description of the transit facilities, equipment, and services be detailed enough in design concept, design scope, and operating policies to model transit ridership (40 CFR Part 93.106(a)(2)(ii), 1997).

4.5 Trip Assignment

The final step in the travel demand model is trip assignment. Since trip assignment can be performed in several different ways, this section separates the discussion by the methods used in each county rather than adhering to the previous format of a general overview followed by the regional comparison. In the Sacramento and San Joaquin Valley travel models, two general methods are used: incremental and equilibrium trip assignment.

Trip assignment is used for assigning vehicles to routes, loading the trip matrix onto the roadway network, and producing among other data: link speeds, link volumes, daily vehicle miles traveled, and daily trips. However, it should be noted that adjustments to link speeds are often used to calibrate link volumes with observed roadway volumes. Thus, link speeds are generally considered to be unreliable as estimates of true roadway speeds. The three primary inputs to the trip assignment step include: the trip matrix, road network with speed curves, and route selection rules (Ortúzar and Willumsen, 1995).

The trip matrix, discussed in the trip distribution section above, provides trip origin and destination data. Speed congestion curves describe the relationship between link speeds and flows. They dictate the rate at which speeds decrease as link volumes increase. Route selection rules, most commonly travel time and monetary costs, are simply the criteria by which routes between trip ends are chosen (Ortúzar and Willumsen, 1995). Since speed congestion curves are necessary regardless of the assignment method used, they will be discussed first. A discussion of the incremental and equilibrium methodologies will follow.

4.5.1 Speed Congestion Curves

In the Sacramento and San Joaquin Valley regions, the speed congestion curves are derived from three sources: the Bureau of Public Roads (BPR) function, the Highway Capacity Manual (HCM) curves, and the Highway Capacity Manual’s method for estimating intersection delay.

Barton-Aschman Associates, Inc. (1996, p.3-116 to 3-118) present the BPR function and the HCM method for estimating intersection delay as follows:

> “The BPR function has long been the “work-horse” volume-delay function for traffic assignments. The function is defined as follows:
>
> $t_f = t_o * (1 + 0.15 * (V/C)^{4.0})$
>
> where:
> t_f = final, congested, link traversal time
> t_o = link traversal time at zero volume
> V = link volume
> C = link capacity

[It] was originally developed on data from the Shirley Highway in suburban Washington, D.C. While it was originally developed from freeway data, it has been generally applied to all links in the highway network. Recently, some regions have made adjustments to the BPR function coefficient (0.15) and exponent (4.0) in an effort to produce more reasonable speed estimates.

Some regions have adopted different volume-delay functions for *arterials* such as the Highway Capacity Manual method for estimating intersection delay. This is also the method used by the Direct Travel Impact Model (DTIM) post-processor. Congested link travel times are assumed to be the sum of link traversal time plus the intersection delay:

$$t_f = t_t + D$$

where: t_t = link traversal time at cruise speed
D = average delay per vehicle at intersections per HCM method below

The link traversal time (in seconds) at cruise speed is computed as follows:

$$t_t = \frac{3600 * \text{length}}{s_1 - A * e^{B * dist}}$$

where: length = the length of the link in miles
s_1 = free-flow speed in miles per hour
A = 18 + (s_1 - 25) / 2.22
B = [(s_1 - 25) / 5] - 9
dist = average distance between signals in miles

The intersection delay is calculated using HCM methods as follows:

$$D = 1.3 * (d_u * DF + d_i)$$

$$d_i = 173 * X^2 * [(X - 1) + [(X - 1)^2 + m * (X / c)]^{1/2}]$$

$$d_u = 0.38 * C * \frac{[1 - (G / C)]^2}{[1 - (G / C) * \text{Min}(X,1.0)]}$$

$$c = [\text{capacity of green per hour}] * [\text{number of lanes}] * [G/C]$$

where: D = approach total delay
d_i = approach incremental delay in seconds (per vehicle)
du = approach uniform delay, in seconds (per vehicle)
C = cycle length in seconds
G = effective green time for lane group in seconds
G/C = green to cycle ratio for lane group
X = v/c ratio for lane group

v/c	=	volume to capacity ratio
v	=	traffic volume per hour
c	=	capacity for the lane group
m	=	a calibration term

> While the DTIM procedure makes use of look-up tables of average signal spacing, cycle lengths, green to cycle ratios, etc., more variation in assumptions is allowed (i.e., through the explicit listing of the factors affecting intersection delay) and a more soundly based delay function is used to estimate congestion delay."

As noted above, the BPR function derives congested link travel times from free-flow times, the V/C ratio on network links, and two function coefficients. Free-flow travel times are calculated using link distances and posted speed limits or travel time surveys conducted by the local agencies. The V/C ratio is a result of the trip assignment process assigning volumes of vehicles to specific links on the road network. The link-specific V/C ratios will change until the final assignment iteration is performed. Some regions "hand-fit" the BPR function to local conditions by changing the coefficients to make the resulting travel times more closely match observed data. These hand-fit curves specify for each volume to capacity ratio, a factor by which the free-flow speed is reduced to reach the congested speed.

In the regions studied, examples of "hand-fitted" BPR curves come from the San Joaquin and Kern County travel models. The adjusted coefficient and exponent values for these counties are listed in Table 4.7 below.

County	Facility Type	Coefficient	Exponent
Bureau of Public Roads	Defaults	0.15	4.0
	Freeway	0.15	4.0
	County Road	0.70	4.0
	Arterial	0.40	4.0
	Collector	0.15	4.0
San Joaquin County	Centroid Connector	0.15	4.0
	SR 120 Connector	0.15	4.0
	Expressway	0.50	4.0
	HOV Lane	0.15	4.0
	HOV Connector	0.15	4.0
Kern County	Freeway	0.15	10.0
	Loop Ramps	0.15	10.0

Table 4.7
"Hand-Fit" Bureau of Public Road Function Coefficients and Exponents
(source: Barton-Aschman Associates, Inc., 1996, DKS Associates, 1994a)

For the remaining facility types in the Kern County travel model, the speed functions are based either on the HCM intersection delay function described earlier (used primarily for arterials), or on the assumption that there is no delay (Barton-Aschman Associates, Inc., 1996).

The last type of speed congestion curves are based initially on the HCM, but subsequently hand-fit by each region according to local travel time studies. These curves are actually a set of factors that are applied directly to free-flow speeds based on link specific V/C ratios. The speed congestion curves for each region are taken from the "*.set" file in each model update report. Table 4.8 below lists a series of V/C ratios and a factor that the free flow speed is reduced by to reach the congested speed. For example, a Sacramento County freeway with a volume-to-capacity ratio of 0.80 will reduce a 60 miles per hour free-flow speed down to a congested speed of 51 mph. (congested speed = 60/1.18).

Supplementing the speed congestion curves, some regions will limit how slow vehicle speeds are allowed to get on highly congested links. In Sacramento, the only region implementing this option, if V/C ratios exceed 2.0, congested speeds are limited to a percentage of the free-flow speeds. On freeways, the congested speed cannot drop below 6 percent of the free flow speed; for expressways, it is 12 percent, and for arterials and collectors, the speed floor is 20 percent of the free-flow speed.

V/C Ratio	Sacramento County			Tulare County						Kings County				Fresno County				
	Fwys	2-lane Arterials	Urban/Suburban Arterials	Fwys	Rural Roads	Arterials/ Collectors	Fwy Ramps (Loop)	Fwy Ramps (Diamond)	Centroid Connector	Fwys	Highways	County Roads	Arterials	Fwys	Rural Roads	Arterials/ Collectors	Fwy Ramps (Loop)	Arterials/ Collectors
0.10	1.00	1.00	1.00	1.00	1.03	1.01	1.03	1.01	1.00	1.01		1.02	1.00	1.00	1.03	1.01	1.03	1.01
0.20			1.01	1.01	1.08	1.02	1.08	1.02		1.03		1.03		1.01	1.08	1.02	1.08	1.02
0.30				1.02	1.14	1.03	1.14	1.03		1.06		1.05		1.02	1.14	1.03	1.14	1.03
0.38											1.06							
0.40	1.01	1.03	1.02	1.03	1.16	1.05	1.16	1.05		1.08		1.06		1.03	1.16	1.05	1.16	1.05
0.44											1.07							
0.50	1.03	1.06	1.04	1.04	1.19	1.09	1.19	1.09		1.10	1.08	1.08		1.04	1.19	1.09	1.19	1.09
0.56											1.09							
0.60	1.06	1.09	1.06	1.06	1.22	1.12	1.22	1.12		1.15		1.10		1.06	1.22	1.12	1.22	1.12
0.63											1.11							
0.69											1.14							
0.70	1.11	1.14	1.09	1.10	1.25	1.18	1.25	1.18		1.20		1.12		1.10	1.25	1.18	1.25	1.18
0.75											1.19							
0.80	1.18	1.22	1.67	1.14	1.28	1.28	1.28	1.28		1.28		1.14		1.14	1.28	1.28	1.28	1.28
0.81											1.26							
0.88											1.36							
0.90	1.30	1.33	2.36	1.25	1.32	1.47	1.32	1.47		1.39		1.16		1.25	1.32	1.47	1.32	1.47
0.94											1.55							
0.95				1.39	1.33	1.64	1.33	1.64		1.53		1.17		1.39	1.33	1.64	1.33	1.64
1.00	1.63	1.62	3.65	2.00	1.33	2.00	1.33	2.00	1.00	1.83	1.95	1.18		2.00	1.33	2.00	1.33	2.00
1.10	1.66	2.16	1.67	3.03	1.61	3.45	1.61	3.45		2.50	2.20	1.50		3.03	1.61	3.45	1.61	3.45
1.15										3.00								
1.20	2.07	3.63	2.36	4.00	1.20	5.90	2.00	5.90			2.50			4.00	2.00	5.90	2.00	5.90
1.25												2.00						
1.30	2.84									4.00								
1.40	3.89	6.97	3.65															
1.50				7.70	3.33	10.00	3.33	10.00			3.00	3.00		7.70	3.33	10.00	3.33	10.00
1.60	6.74	9.58	4.51															
1.70										6.00		4.00						
1.80	10.61	10.62	4.83															
1.90																		
2.00	15.77	10.98	4.94	10.00	10.00	10.00	10.00	10.00	1.00		4.00			10.00	10.00	10.00	10.00	10.00
327.00	16.00	11.18	5.00	10.00	10.00	10.00	10.00	10.00	1.00	6.00	4.00	4.00	1.00	10.00	10.00	10.00	10.00	10.00

Table 4.8
Speed Congestion Curves
(sources: SACOG, 1999a; DKS Assoc., 1996; Dowling Assoc., 1995; DKS Assoc., 1995)

4.5.2 Incremental Trip Assignment

The incremental trip assignment methodology is based on the premise that loading the trip matrix onto the network *incrementally* results in reasonable congested link speeds and volumes. Incremental assignment is accomplished by dividing the trip matrix into "fractional matrices by applying a set of proportional factors." (Ortúzar and Willumsen, 1995) These factors are typically 0.4, 0.3, 0.2, and 0.1, however, they may be changed to the model builder's preferences (Ortúzar and Willumsen, 1995). As each fractional matrix is loaded onto the network, congested speeds are recalculated, influencing the route selection for the following matrix. As congestion on the roadways increase, associated costs also increase; new trips divert to faster routes. The limitation of incremental assignment is that once traffic flows have been assigned to the network, they cannot be removed even if the initial iterations assign too much to a particular link. On the other hand, the advantages are that: a) incremental assignment is easy to program, and b) the results can be interpreted as the build-up of congestion for the peak period (Ortúzar and Willumsen, 1995).

Madera County and Kings County both use the incremental assignment methodology. The documentation obtained from Kings County provides a practical example of how a seven-pass incremental capacity constrained assignment technique is used. Dowling Associates (1995, p.25) describe the process as follows:

> "The principal feature of the incremental capacity-constrained process is that it models the effect of congestion on travel time. The process works as follows: for the first 20% assignment, all traffic is assigned to the minimum path. The assignment module then computes the assigned volume/capacity ratio and determines an appropriate reduction from the original free flow speed based on this ratio. The second increment of 20% is assigned to the network using the computed reduced segment speeds. The process is repeated for succeeding increments of 20, 10, 10, 10 and 10%, leading to a complete 100% assignment of the trip table. Behaviorally, this technique replicates the buildup of the typical peak hour in which the first cars onto the system take the shortest path. As congestion builds throughout the hour, some people will take alternative routes to avoid congestion. The several increments allow the gradual buildup of congestion to be modeled, with more people taking alternate routes as congestion builds…" ~~(Dowling Associates, 1995)"~~

The amount of the reduction of free flow speeds due to congestion is determined by the speed congestion curves for the region. See Table 4.8 for examples of the curves.

4.5.3 Equilibrium Trip Assignment

The remaining counties studied in this report use the equilibrium assignment methodology. Equilibrium trip assignment is an iterative process which begins by assuming that all vehicles will travel on the fastest route between destinations regardless of the congestion caused by other cars. In subsequent iterations, travel times are recalculated based on the estimated link volumes, and trips are reassigned to alternative routes based on the congested speeds. After each iteration, traffic is shifted to alternative routes with equal or faster travel times. The ultimate objective is to reach "equilibrium," or the point at which no driver can shift to an alternative route with a faster travel time (DKS Associates, 1995).

Traffic can be assigned daily or by time periods. The counties of Merced, Madera, and Kings use daily assignment, while Fresno and Tulare base their assignments on AM, PM, and off-peak time periods. San Joaquin County assigns traffic daily, and then factors the AM and PM peak periods. Kern incorporates the most time periods, assigning traffic for an AM peak, PM peak, mid-day peak and an off-peak period.

After the assignment step, regions with higher levels of congestion generally incorporate a feedback loop back to the trip generation or trip distribution step, depending on how complex the model is. All of the feedback loops utilized for the regions in this study link trip assignment with trip distribution. There are a couple of different ways used to calculate the feedback loop. These will be addressed in the following section.

4.6 Feedback Loops

Feedback loops in the study regions have been discussed periodically throughout this report as linking the trip assignment step back to trip distribution. The purpose for this loop is to redistribute trips based on congested speeds rather than the free-flow speeds used in the initial distribution (Ortúzar and Willumsen, 1995). In congested areas, using free-flow speeds in the distribution step will tend to produce higher link speeds, and over-estimate the number of long distance trips (DKS Associates, 1996). For these cases, using the congested speeds for trip distribution makes more intuitive sense, and produces more reasonable results.

Some of the models in the study area do not use a feedback loop. In Kings County and Madera County, no feedback loop is necessary since they are using the incremental assignment methodology. Congested speeds are recalculated with each fractional assignment. San Joaquin County does not use a feedback loop either.

Among the counties using a feedback loop, the configuration of the loop process itself may differ from region to region. The Federal Highway Administration's report "Incorporating Feedback in Travel Forecasting: Methods, Pitfalls and Common Concerns" (1996), describes in detail four methods for introducing feedback:

- "*Method of Successive Averages with Equilibrium Assignment (MSA-EQA)* – provides equal weight to each previous iteration's equilibrium assignment results.
- *Method of Successive Averages with All-or-Nothing Assignment (MSA-AON)* – same as MSA-EQA, but each assignment is made on a single best-path basis.
- *Method of Optimal Weighting with Equilibrium Assignment (MOW-EQA)* – computes as optimal weighting for each iteration's equilibrium assignment.
- *Method of Optimal Weighting with All-or-Nothing Assignment (MOW-AON)* – same as MOW-EQA but each assignment is made on a single best-path basis.

> "For all four of these alternative methods, the volumes from previous iterations are averaged with the volumes from the most recent assignment and new input speeds are determined based upon the averaged volumes. The speeds from previous iterations are not averaged directly because of the non-linear relationship between volume, capacity, and speed. All of these methods address the way in which output from assignment is manipulated prior to reintroduction as input to a previous step. The applications of any one of the alternative approaches is basically the same regardless of where in the four step process the assignment data are being fed back." (FHWA 1996)

Within the study area, the MSA-EQA most closely describes the methods used. Generally, the MSA-EQA combines the results from previous iterations and the current iteration to produce updated volumes and trip tables. With the MSA, all iterations have equal weight, and it has been shown to always converge (FHWA, 1996). The use of a full equilibrium assignment instead of an all-or-nothing assignment speeds up the convergence process, reducing the number of iterations needed for completion.

In SACMET, a "direction-step" option is used. A "direction-step" is similar to the MSA in that it takes volumes from a previous trip table and combines them with the current one, except that all the iterations do not have equal weight. In Sacramento, instead of providing equal weight to previous iterations, 75% of the current trip table is combined with 25% of the previous. This process is repeated until less than 1 percent of the zone-to-zone travel times change by more than 5 percent from one loop to the next. In the base year, three loops are needed to converge. By 2005, four loops are necessary, and in 2015, five loops are required (SACOG, 1999a).

The trip tables used in the feedback loop differ for each trip purpose. The home-based work trip distribution and mode choice step uses travel times taken from an AM peak period traffic assignment. For the trip distribution and mode choice steps of all other trip purposes, travel times are taken from an off-peak traffic assignment (DKS Associates, 1994b).

The feedback process used in Fresno and Tulare counties is essentially the same as Sacramento, following the MSA-EQA method. DKS Associates (1995, 1996), the developer for both models, call the feedback method a "simplified feedback loop with one interpolation." The "interpolation" is the combination of the results from a previous cycle with those of the current cycle. The results are then used as an input to the next cycle. The logic behind this method is that the correct solution (congested speeds, in this case) lies somewhere between the previous two cycles. As was the case in SACMET, a "direction-step" is used to more precisely estimate the correct amount of interpolation between cycles. Unlike Sacramento, however, the Fresno and Tulare models contain only a single interpolation. During the development of the model, it was decided that one interpolation was sufficient to provide a consistent estimate of congested travel speed, while at the same time controlling the time required to run the model.

> The feedback methods in Fresno and Tulare counties follow the following seven steps (DKS Associates, 1995, 1996):

1. “The initial daily trip distribution is estimated using uncongested travel speeds.
2. The A.M. peak period and off-peak period trips are factored from the daily trips and assigned separately to the road network.
3. Congested travel speeds and times are calculated for both A.M. peak and off-peak congestion levels.
4. The daily trip distribution is recalculated assuming all trips travel at A.M. peak period congested speeds.
5. The daily trip distribution is recalculated assuming all trips travel at off-peak period congested speeds.
6. The actual daily trip distribution for each trip purpose includes some trips which travel during peak times and some which travel during off-peak conditions. The final daily trip distribution is calculated by interpolating between the two daily trip distribution estimates (peak speeds, off-peak speeds). The interpolation factors are different for each of the five trip purposes, and are based on the percentage of trips which occur during the peak six hours versus the off-peak 18-hours.
7. The final peak period and off-peak trips and traffic assignments are based on the interpolated daily trip distribution.”

Neither the Fresno nor Tulare travel model need feedback loops in the base year. As growth occurs, however, increased congestion levels make it necessary to incorporate feedbacks into future year analyses.

4.6.1 Conformity Implications

The impact of feedback loops on conformity analyses will vary widely. The deciding factor is the level of congestion on the roadway network. The more congestion there is, the greater the impact brought about by the feedback (Niemeier et. al, 1998). Changes induced by incorporating feedback can include (Louden, et al, 1997):

- increased average link speeds
- decreased average travel time
- decreased average travel distance
- lower system VMT

Note that link speeds and system VMT are affected. These data are used directly in the emissions models that are in turn used to obtain the regional emissions estimates. In areas with significant congestion levels, the incorporation of a feedback loop will most likely change the conformity results. This being said, however, it is difficult to determine in general, extent or direction of the impact. Incorporating feedback in an area with high congestion levels could alter the network in many ways, including the shifting of congested areas within the region.

Within the study area, implementation of feedback loops has occurred in areas that demonstrate a need for them based on current or projected congestion levels. While the precise emissions impact is undetermined, it is clear that the incorporation of feedbacks has increased the accuracy of link speeds in the travel models.

5.0 The Emission Models

Thus far in the report, the discussion has focused largely on travel times and speeds within the travel modeling process. Detailed descriptions of congested link travel time calculations have been provided, along with discussion on the uses of these travel times within the travel model. The federal Conformity requirements extend beyond the travel modeling process, however, and incorporate the use of emission models. These emission models depend on the reasonableness of link speeds generated from the travel models for VMT by speed distributions and by time period.

There are currently two emission modeling packages utilized in California. The Motor Vehicle Emission Inventory (MVEI) model developed by the California Air Resources Board and the Direct Travel Impact Model (DTIM) developed by Caltrans.

5.1 The Motor Vehicle Emission Inventory Modeling Suite (MVEI)

The California Air Resources Board (ARB) has developed a suite of models designed to estimate on-road emissions. The most current version of the motor vehicle emission inventory, MVEI7G, consists of four models: CALIMFAC, WEIGHT, EMFAC, and BURDEN (see Figure 3.1 for the MVEI model process). BURDEN, the final component of MVEI, calculates emission estimates using emission factors obtained from EMFAC and “vehicle activity data,” some of which is taken from the travel model outputs. It is important to note that vehicle activity data from the travel model, consisting of vehicle trips and vehicle miles traveled on the network is the only link between the travel and emission models.

5.1.1 CALifornia Inspection and Maintenance Emission FACtors Model (CALIMFAC)

The California Inspection and Maintenance Emission Factor Model (CALIMFAC) is the first component in the MVEI modeling suite. This model takes data from three vehicle testing programs (Surveillance, Random Roadside, and I/M Evaluation) and produces *base emission rates* (BERs) for different inspection and maintenance (I/M) scenarios (ARB, 1996a). Base emission rates are vehicle emissions per odometer mileage, and are developed for each:

- vehicle class (see Table 5.1)
- vehicle technology (see Table 5.1)
- vehicle model year (1970 to 2020)
- pollutant (TOG, CO, NO_x, PM_{10})
- and process (exhaust and evaporative)

Vehicles identified through the I/M programs are tested on a dynamometer, and their tailpipe emissions are captured into “bags.” The dynamometer testing involves driving the vehicle through a drive cycle that is designed to reflect actual driving conditions. The most well-known drive cycle is the Federal Test Procedure (FTP), which is used by vehicle manufacturers to certify new vehicles (ARB, 1996a).

Once the base emission rates have been calculated, they are adjusted by WEIGHT and EMFAC to account for various “factors” (described below) before they are applied to the travel activity data from the travel demand model.

Vehicle Class	**Technology Group**
Light-duty autos	non-catalyst, catalyst equipped, diesel
Light-duty trucks	non-catalyst, catalyst equipped, diesel
Medium-duty trucks	non-catalyst, catalyst equipped
Light-heavy Gas trucks	non-catalyst, catalyst equipped
Light-heavy diesel trucks	diesel
Medium-heavy gas trucks	non-catalyst, catalyst equipped
Medium-heavy diesel trucks	diesel
Heavy-heavy diesal trucks	diesel
Urban transit buses	diesel
Motorcycles	non-catalyst

Table 5.1
Vehicle Classes and Technology Groups
(source: ARB, 1996a)

5.1.2 Activity WEIGHTing Model (WEIGHT)

The second component in the MVEI modeling suite is the Activity Weighting Model, WEIGHT. The outputs of this model include (ARB, 1996c):

- average vehicle accumulated mileage,
- fractions of vehicle activities attributable to particular model years according to vehicle age,
- fractions of vehicle activities attributable to different technologies within a vehicle class,
- fractions of heavy-duty truck activity by weight class.

The *average vehicle accumulated mileage* is the average odometer by model year in a specific calendar year. These data are used by EMFAC, along with the basic emission rates from CALIMFAC to obtain model year emission factors (ARB, 1996a).

WEIGHT also produces vehicle activity fractions by model year and technology class. The model year vehicle activity fractions are necessary for developing the *fleet composite emission factors* in EMFAC. EMFAC produces one emission factor for the fleet of vehicles described by a vehicle class and specific technology for a particular calendar year. The model year fractions provided by WEIGHT are combined with model year emission factors for a particular year to obtain a specific calendar year’s fleet composite emission factor (ARB, 1996c).

The travel fractions by *technology group*, on the other hand, are direct inputs into BURDEN. Instead of being used to *combine* model year emission factors, the technology fractions are used to *split* the activity data by vehicle class from the travel models into technology groups (ARB, 1996c).

The travel fractions by model year, technology group, and for heavy duty trucks, consist of three different types: vehicle population travel fractions, starts travel fractions, and VMT travel fractions (ARB, 1996c). The following discussion focuses on the development of the VMT travel fraction, since the VMT information used in its development is analogous, but not the same as, the VMT derived from the travel model.

It is important to reiterate that the VMT estimates used to obtain the VMT travel fractions *are not* the same VMT estimates derived from the regional travel models. For each model year, the vehicle population travel fraction is multiplied by the accrural rate to produce the relative number of miles traveled statewide per model year. The relative miles of all model years are then summed to produce the total relative miles traveled by each vehicle class or technology group (ARB, 1996c).

The VMT travel fraction function is described mathematically as follows (ARB, 1996c):

$$\text{Relative Miles}_{MY} = \text{Population Travel Fraction}_{MY} * \text{Accrual Rate}_{MY}$$

$$\text{VMT Travel Fraction}_{MY} = \frac{(\text{Relative Miles})_{MY}}{\text{SUM}_{(MY=1\text{-}35)}\,[\text{Relative Miles}_{MY}]}$$

where: MY = model year

5.1.3 EMission FACtor Model (EMFAC)

As noted above, EMFAC produces "fleet composite" emission factors. In other words, it estimates calendar year-specific on-road motor vehicle emission factors by multiplying each model year's emission rate by its travel fraction (relative use or prevalence in the fleet) (ARB, 1996a). Similar to the base emission rates, composite emission factors are categorized in a variety of ways (see Table 5.2).

EMFAC Fleet Composite Emission Factors are categorized by:

Model Year	1970 to 2020
Pollutant Type	Carbon Monoxide (CO)
	Carbon Dioxide (CO2)
	Hydrocarbons (HC)
	Nitrogen Oxides (NO_x)
	Particulate Matter from Exhaust (PMEX)
	Particulate Matter from Tire Wear (PMTW)

	Particulate Matter from Break Wear (PMBW) Reactive Organic Gas (ROG) Total Organic Gas (TOG) Volatile Organic Compounds (VOC)
Season	Summer Winter
Speed Range	0mph to 65mph in 5mph increments (14 “bins”)
Temperature	30° to 110° F
Vehicle Class	Table 6._ above
Vehicle Technology	Table 6._ above
Vehicle Process	Exhaust Starts Exhaust Stabilized Running Evaporative Hot Soak Evaporative Diurnal Evaporative Resting Losses Evaporative Running Losses

Table 5.2
EMFAC Fleet Composite Emission Factor Categories
(source: ARB, 1996b)

EMFAC also adjusts for errors in the emission modeling process. In particular, the FTP (and drive cycles in general), suffer from a number of errors in their ability to estimate actual driving patterns. To account for some of the deficiencies, the following types of correction factors (used as multipliers) are utilized:

- Start Correction Factor
- Bag Correction Factor
- Speed Correction Factor
- Temperature Correction Factor
- Fuel Correction Factor
- Cycle Correction Factor
- High Emitter Correction Factor

For additional detail regarding the correction factors, please refer to the ARB methodology report Volume II (ARB, 1996b).

5.1.4 BURDEN

The final component in the motor vehicle emission inventory modeling suite is BURDEN; so named because it estimates the emissions BURDEN placed on the atmosphere (ARB, 1996d).

Put simply, BURDEN calculates emission estimates using emission factors from EMFAC and activity data from the vehicle activity data file.

The vehicle activity data file contains vehicle population, miles traveled, and starts information for each vehicle class and for specific years. VMT from the regional travel demand models is used in the development of this activity file.

Procedurally, the activity data is first divided into six time periods (see Table 5.3). Note that these time periods are distinctly different from the "peak periods" discussed in the travel model sections. For each of the six time periods, BURDEN models different ambient temperatures, levels of vehicle activity, and speed distributions for each vehicle class, technology group, process, and pollutant. The final daily emission estimates equal the sum of the emission estimates from each time period, and are provided for each pollutant in tons per day for a specific season, county, and inventory year. Table 5.4 includes the types of data and agency sources used for this process.

Time Periods		
12:00am	to	6:00am
6:00am	to	9:00am
9:00am	to	12:00pm
12:00pm	to	3:00pm
3:00pm	to	6:00pm
6:00pm	to	12:00am

Table 5.3
BURDEN Time Periods
(source: ARB vol. 4)

Data Types	Data Sources
Vehicle Population	California Department of Motor Vehicles, California Department of Finance
VMT	Caltrans, regional travel demand models
Starts	US Environmental Protection Agency, Caltrans, CA Air Resources Board
Ambient Temperature	National Weather Service, state agencies, air pollution control districts
VMT by Speed Distributions	US Environmental Protection Agency, CA Air Resources Board, regional travel demand models
Soak Distribution	US Environmental Protection Agency, CA Air Resources Board
Period Splits	Caltrans, regional travel demand models

Table 5.4
BURDEN Data Sources
(source: ARB, 1996a and 5)

Continuing to examine the link between travel demand models and the emission models, the inputs to BURDEN that hold the most interest in terms of the topics covered in this report are: VMT, VMT speed distributions, and vehicle starts.

Vehicle Miles Traveled. An important component of BURDEN, and one of the significant contributions of the travel demand model is VMT. VMT is used by BURDEN to estimate emissions of: total organic gasses, reactive organic gasses, carbon monoxide, oxides of nitrogen, and particulate matter. The initial estimates of VMT for the activity data file come from Caltrans, and if available, the regional travel demand models. Within the study area, Sacramento region, Fresno, Kern, Merced, San Joaquin, Stanislaus, and Tulare counties all provide total VMT estimates, while Kings and Madera county use the Caltrans defaults.

As noted above, the activity data must be split into the six planning periods. For VMT, this is done using information from the Caltrans Statewide Travel Survey. Once the data is split, the time period split fractions are used for all base and future model years (ARB, 1996e). For counties which submit total VMT estimates, ARB staff applies the time period split fractions to disaggregate the data into the required time periods.

An analogous procedure is used to obtain the VMT by vehicle class breakdown. Caltrans develops vehicle class fractions using the data sources listed in Table 5.5. VMT estimates are obtained for urban buses, heavy-duty trucks, and motorcycles, and then subtracted from the total VMT in the "Motor Vehicle Stock, Travel and Fuel Forecasting Report (MVSTAFF)." The remaining VMT are split between the remaining vehicle classes (light and medium duty vehicles) using Department of Motor Vehicle registration data (ARB, 1996a).

Vehicle Class	Source	Report
Light and medium-duty vehicle	Caltrans	"Motor Vehicle Stock, Travel and Fuel Forecasting Report"
Heavy duty truck	Caltrans	"Truck Kilometers of Travel on the CA State Highway System"
	Pacific Environmental Services	"Assessment of Heavy-Duty Vehicle Usage in CA: Population and Use Patterns"
Bus	CA Air Resource Board: Mobile Source Division	1989 Transit Bus Survey
Motorcycle	CA Department of Motor Vehicles	motorcycle registration

Table 5.5

The 1993 version of the MVSTAFF report is used in the "7G" version of MVEI. It covers 1980-1993 data, and provides some projections into future years. For years not covered by the report, ARB staff interpolates and extrapolates data as needed (ARB, 1996a).

VMT by Speed Distribution. Since BURDEN uses 14 different speed bins, the VMT data in the activity file must be broken down by speed distribution as well. The Caltrans speed distribution estimates come from traffic counts on urban freeways and the highway performance monitoring system (HPMS) (ARB, 1996a). The speed distributions from Caltrans are used for all vehicle classes except buses, and do not change by year. When speed distributions are available from travel models, they can change by peak versus off-peak periods as well as by calendar year (ARB, 1996e). Bus VMT by speed data are derived from the Valley Research Corporation report, "Urban Bus Population and Usage." (ARB, 1996a).

HPMS provides estimates of VMT on 6 facility types in 3 geographical area types. Facility type and geographic area inputs are obtained directly from the local counties. Based on this information, the proportion of travel on each facility type is estimated, and a "typical" VMT by speed distribution is developed. Vehicle speeds are obtained from traffic counts by speed collected by Caltrans for the California Highway Patrol (ARB, 1996e). The sum of the typical speed distributions for each facility and geographical condition, weighted by the proportion of travel on each facility type from HPMS, is used as the default speed distribution in BURDEN.

HPMS is regarded as a benchmark for VMT estimates. During the calibration of the regional travel models, VMT estimates derived from the regional models are compared to the HPMS VMT estimates for that region. The difference between the two must not be statistically significant. If it is, corrections to the travel model must be made before it can be considered "calibrated." Once a regional model has been calibrated to HPMS, however, the regional data obtained from the model is generally regarded as more accurate than Caltrans-derived data. The logic behind this reasoning is that the while HPMS provides sound VMT data, the region-specific nature of the travel demand models allows more accuracy in the additional activity data they provide. For this reason, regional data is considered more valuable as a whole.

In terms of the vehicle speed distribution data, however, all of the regions rely on default values developed by Mike Bitner from the Council of Fresno County Governments. Mr. Bitner wrote computer code that enabled him to generate VMT by speed distribution from MINUTP. His results were provided to CARB and are used in the MVEI7G model series. The procedure is as follows (Bitner, 1998):

> "The following methodology has been developed by Fresno COG to obtain the model speed distribution...
>
> First, BURDEN uses 14 speed distribution bins as follows:

```
Bin              BURDEN labels as

0    - 7.5        0 -  5
7.5  - 12.5       5 - 10
12.5 - 17.5      10 - 15
17.5 - 22.5      15 - 20
............   ...........
62.5 - 67.5      60 - 65
67.5 - 72.5+     65 - 70 and above
```

It is desirable to duplicate these speed groupings from MINUTP for use in BURDEN.A simple NETMRG routine will create an ASCII file of congested speed which can then be imported into your favorite spreadsheet. From there you can calculate the numbers required.

```
*PGM NETMRG NUL, FILE21.DAT         Read in your assigned network
$
$compute speeds for BURDEN speed distribution
$
$  Note: if you have volumes on external Links you may want to
$       skip those capacity classes in order to avoid calculating
$       VMT and speeds on them!
$
$
COMP VMT=VOL*(DIST/100)
SUM VMT
$
$ computes VMT
$
COMP CONGSPD=CSPD
TAB VMT,CONGSPD=0-800-5
$
$table congested speed by vmt by speed @ .5 mile increments.
$
*END
```

This will create a print file which looks something like the following:

```
Tab

CONGSPD   VMT
------------------------------------------
......
225-229   31085
230-234   24075
235-239   20555
240-244   25000
245-249   30667
......etc....
```

Explanation of above:
Speed group 22.5 - 22.9 mph has 31,085 VMT
Speed group 23.0 - 23.4 mph has 24,075 VMT

> You can see that by using your spreadsheet you can easily create the required speed bins for BURDEN. Remember, your speed bins contain the percentage of total fleet VMT at different speeds.
>
> Thanks to Dennis Wade of the ARB for his help with the BURDEN speeds."

Vehicle Starts. The third and final link between the travel model and emission model is the total number of vehicle starts. Vehicle starts are important for accounting for non-destination trips (short side trips, moving cars in a parking lot, shuffling car at home, etc.). Every time a car is started, emissions are released that need to be included in the model.

The basic vehicle starts data come from the U.S. EPA's 3-City Instrumented Vehicle Study, with Caltrans survey data filling in the gaps (CARB, 1996a). Since the survey data recorded *trips* rather than starts, a "trip to starts" adjustment factor was calculated. Where applicable, this adjustment factor is applied to total trip estimates from regional travel models to obtain the total number of starts in a region.

In the study region, the counties which provide trip data from their regional travel model include (CARB, 1996e):

- Fresno County
- Kern County
- Merced County
- San Joaquin County
- Stanislaus County
- Tulare County

Calculating Emission Estimates. Once the necessary data has been compiled and transformed into the correct form, the calculation of the final emission estimates is fairly straight forward. For running exhaust emissions, for example, the emission factors by speed and county temperature provided by EMFAC are multiplied by the fraction of VMT for each speed group. The result are weighted emission factors for each speed group. These factors are summed, then multiplied by the VMT by time period to produce the total emissions for each period. All six time periods are summed to get the total running exhaust emissions for a particular pollutant (ARB, 1996d). Emission estimates are produced for each modeled year, and broken down by vehicle class and pollutant.

5.2 The Direct Travel Impact Model (DTIM)

Another model that is used as an alternative to BURDEN to calculate the final emission estimates is the Direct Travel Impact Model (DTIM) developed by Caltrans. This model was originally developed to provide detailed emission inputs for photochemical grid models such as the Urban Airshed Model, but has since been applied to estimating regional motor vehicle emissions for Conformity purposes (Caltrans, 1999). SACOG is the only agency covered in this report currently using DTIM.

The DTIM model consists of a series of three programs: CONVIRS3, IRS3, and DTIM3.1. The primary inputs to the model include the activity data from the travel models and the emission rates from EMFAC, however additional files are necessary as well. CONVIRS3 uses the emission rates for all vehicle classes from EMFAC, reformats, and sorts them for use in IRS3. IRS3, in turn, produces fleet average emission rates which DTIM3.1 then combines with the activity data from the regional travel models to produce the regional emission estimates.

CONVIRS3 and IRS3 are similar in function to EMFAC, in that they are the programs which create the emission rates. Although CONVIRS3 and IRS3 use EMFAC outputs, they are in effect converting the emission rates into a usable form for DTIM. Likewise, DTIM3.1 is similar to BURDEN. It takes the emission factors, along with other information, and produces the regional emission estimates.

5.3 Regional Emission Modeling

Regional emission modeling practices in the study area generally follow the sequence of model processes described in this report. A slight procedural addition to this process was implemented by the San Joaquin Valley. The emission modeling for the 1998 conformity determinations in San Joaquin Valley was completed using a batch file program developed by ENVIRON. This batch file was developed to run both EMFAC/BURDEN7F and MVEI7G with minimal inputs. The models themselves were not altered, and the addition of this batch file did not change the resulting emission estimates. Each jurisdiction ran the batch file for their own area by specifying the air district they were located in, analysis year, VMT and trip information from the travel model, and an output file name. With that information, the batch file was able to select the county-specific information from the BURDEN defaults, and run the models. The batch file was developed with the input and oversight of Dennis Wade from the ARB.

6.0 Post-Processing Worksheets

Once the travel and emission models have been run, there remains one final step before the emission estimates can be used to demonstrate conformity; the emission estimates from BURDEN or DTIM must be post-processed to account for programs and pollution sources not included in the emission models.

6.1 Ozone Post-Processing Spreadsheet

The state implementation plan for ozone was developed using EMFAC7F, the model prior to MVEI7G. After the ozone SIP was completed, future year control measures for ozone precursor pollutants (NO_x, ROG) were implemented and/or planned on the state and federal level. The spreadsheets used in post-processing ozone precursor emissions calculate the impact of these control measures on future year emissions. For a sample spreadsheets of the control factors for Fresno County, see Appendix C.

The emission estimates from BURDEN are adjusted by vehicle class for: heavy duty diesel, enhanced I/M programs, state, and federal measures. Since control measures take effect over a number of years, the impact is felt in different proportions over time. To account for this, control measure factors are developed for: 1999, 2002, 2005, 2008, and 2010.

6.2 San Joaquin Valley PM_{10} Plan Conformity Worksheet

During the development of the PM_{10} emission budgets for the San Joaquin Valley's PM_{10} Attainment Demonstration Plan, the San Joaquin Valley Air Pollution Control District, in coordination with the Valley COGs, produced a worksheet that incorporates motor vehicle-related PM_{10} emissions with MVEI7G outputs. See Appendix D for the full worksheet documentation.

PM_{10} emissions from motor vehicles come from a number of sources including paved and unpaved roads, motor vehicle exhaust, and tire and brake wear. The function of the worksheet is to calculate the paved road motor vehicle emissions and sum them with the unpaved road emissions calculated by the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD), and the motor vehicle exhaust, tire and brake wear calculated in BURDEN.

The PM_{10} Plan Conformity Worksheet is made up of eighteen different tables, each serving as input cells, default values, or calculations. Documentation for the data used in the worksheet is available from the SJVUAPCD.

7.0 Conformity Budgets

The final step in the conformity process is determining whether or not the modeled emission estimates are within the budgets established in the state implementation plan. Table 7.1 compares the relevant SIP emission budgets with the associated emission projections modeled by each agency in the study area. As of the writing of this document, all regions are currently in conformity with the applicable transportation air quality regulations.

	Sacramento Valley Air Basin		*San Joaquin Valley Air Basin*					
	Sacramento County		**Fresno County**		**Kern County**			
Current SIP Budgets / Most recent Conformity					**SJV Air Basin**		**Mojave Desert Air Basin**	
	Sacramento		***Fresno***		***Bakersfield***			
Carbon Monoxide (tpd)	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**		
1995	**780**	421.10	**296**	n/a	**223**	n/a		
1999				213				
2001				*196*				
2003						*140*		
2005		215.33		158		129		
2010				149		118		
2015		*163.45*						
2016								
2018				*174*		*158*		
2020						160		
2022		163.53						
Ozone (tpd)	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**
1999 VOC	49.99	40.26	**19.18**	18.47	**15.88**	14.66	**3.05**	2.68
1999 NOx	77.91	77.87	**34.00**	33.02	**26.21**	23.51	**7.46**	6.65
2001 VOC				*17.18*				
2001 NOx				*33.70*				
2002 VOC	*39.67*	*32.27*						
2002 NOx	*70.25*	*69.35*						
2003 VOC						*11.46*		*2.21*
2003 NOx						*21.85*		*6.44*
2005 VOC	**31.32**	24.99						
2005 NOx	**61.35**	59.68						
2008 VOC				*12.59*				
2008 NOx				*28.13*				
2010 VOC				9.08		7.29		1.42
2010 NOx				26.00		17.65		5.11
2015 VOC		16.84						
2015 NOx		52.21						
2018 VOC				11.73		9.49		1.83
2018 NOx				33.18		23.45		6.77
2020 VOC						*10.18*		*1.98*
2020 NOx						*25.60*		*7.37*
2022 VOC		16.60						
2022 NOx		55.53						
	Sacramento County Only							
PM_{10} (tpd)	**No Build**	**Build**	**No Build**	**Build**	**Budget**	**Modeled**	**Budget**	**Modeled**
2000 PM_{10}	**29.04**	28.89						
2001 PM_{10}			**26.31**	23.58	**13.97**	13.74	**2.18**	1.91
2001 NOx			**43.77**	39.18	**35.13**	29.29		
2001 VOC			**28.70**	23.31	**22.77**	17.60		
2003 PM_{10}*			***24.24***	*24.05*	***14.39***	*14.04*		*1.95*
2003 NOx*			***40.59***	*36.49*	***32.85***	*27.05*		
2003 VOC*			***24.86***	*20.17*	***19.80***	*15.31*		
2005 PM_{10}	***32.88***	*31.74*						
2006 PM_{10}			**25.19**	25.14	**15.03**	14.72		
2006 NOx			**35.83**	31.35	**29.43**	23.66		
2006 VOC			**19.11**	15.84	**15.35**	11.70		
2008 PM_{10}*								
2008 NOx*								
2008 VOC*								
2010 PM_{10}			**26.14**	26.06	**15.56**	15.18	**2.17**	2.06
2010 NOx			**34.60**	27.40	**28.59**	20.93		
2010 VOC			**16.29**	11.30	**12.93**	8.46		
2015 PM_{10}	**42.88**	40.81						
2016 PM_{10}								
2016 NOx								
2016 VOC								
2018 PM_{10}			**28.04**	28.02	**16.61**	16.48		1.56
2018 NOx			**32.15**	26.64	**26.93**	22.53		
2018 VOC			**10.66**	8.49	**8.10**	6.38		
2020 PM_{10}					***16.87***	*16.65*		*1.73*
2020 NOx					***26.51***	*22.24*		
2020 VOC					***6.89***	*5.66*		
2022 PM_{10}	***48.00***	*45.29*						

* Budgets were interpolated

Table 7.1

Regional Emission Budgets and Confomity Estimates

	Merced County		San JoaquinValley Air Basin (con.) Stanislaus Co.		San Joaquin Co.		Tulare County	
Current SIP Budgets / Most recent Conformity								
			Modesto		*Stockton*			
Carbon Monoxide (tpd)			**Budget**	**Modeled**	**Budget**	**Modeled**		
1995			**177**	n/a	**261**	n/a		
1999								
2001				*94.56*		*159*		
2003								
2005				90.16		130		
2010				78.29		116		
2015								
2016				*89.07*				
2018								
2020				96.45		147		
2022								
Ozone (tpd)	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**
1999 VOC	**7.32**	7.31	**10.29**	9.19	**14.16**	13.29	**12.05**	10.44
1999 NOx	**20.38**	19.40	**19.43**	19.33	**30.01**	28.87	**21.55**	16.78
2001 VOC		*6.58*		*7.66*		*11.89*		
2001 NOx		*18.90*		*17.51*		*28.67*		
2002 VOC								
2002 NOx								
2003 VOC								*8.47*
2003 NOx								*15.68*
2005 VOC								
2005 NOx								
2008 VOC		*3.83*						
2008 NOx		*14.50*						
2010 VOC				4.93		6.78		5.53
2010 NOx				15.83		22.82		15.88
2015 VOC								
2015 NOx								
2018 VOC		3.46						7.03
2018 NOx		13.72						21.20
2020 VOC				*4.77*		*8.40*		
2020 NOx				*10.38*		*28.80*		
2022 VOC								
2022 NOx								
PM_{10} (tpd)	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**	**Budget**	**Modeled**
2000 PM_{10}								
2001 PM_{10}	**8.11**	7.97	**3.94**	10.25	**8.35**	7.83	**8.06**	7.76
2001 NOx	**20.63**	16.21	**21.75**	19.50	**32.84**	25.82	**24.21**	20.03
2001 VOC	**8.36**	6.56	**12.83**	10.25	**17.94**	13.41	**14.80**	10.99
2003 PM_{10}*	***8.27***	*82.00*	***4.10***	*4.00*	***8.57***	*7.92*	***8.34***	*7.94*
2003 NOx*	***18.98***	*14.61*	***19.93***	*17.97*	***30.22***	*24.00*	***22.28***	*18.51*
2003 VOC*	***7.41***	*5.80*	***11.02***	*8.78*	***15.30***	*11.42*	***12.77***	*9.48*
2005 PM_{10}								
2006 PM_{10}	**8.52**	8.12	**4.34**	4.28	**8.89**	8.45	**8.75**	8.43
2006 NOx	**16.51**	12.60	**17.21**	15.06	**26.30**	21.33	**19.39**	16.27
2006 VOC	**5.99**	4.79	**8.31**	6.64	**11.34**	8.76	**9.72**	7.49
2008 PM_{10}*	***8.69***	*8.15*						
2008 NOx*	***16.19***	*12.24*						
2008 VOC*	***5.57***	*4.45*						
2010 PM_{10}			**4.73**	4.53	**9.34**	9.00	**9.21**	8.67
2010 NOx			**16.60**	12.64	**25.11**	19.36	**18.51**	13.45
2010 VOC			**7.04**	4.80	**9.38**	6.43	**8.15**	5.21
2015 PM_{10}								
2016 PM_{10}			**5.31**	5.04				
2016 NOx			**15.69**	11.59				
2016 VOC			**5.13**	3.52				
2018 PM_{10}	**9.38**	8.63					**10.13**	9.49
2018 NOx	**14.90**	10.43					**16.74**	13.36
2018 VOC	**3.90**	3.02					**5.02**	3.74
2020 PM_{10}			***5.70***	*5.27*	***10.46***	*10.14*		
2020 NOx			***15.08***	*11.67*	***22.12***	*18.81*		
2020 VOC			***3.86***	*2.94*	***4.49***	*3.79*		
2022 PM_{10}								

* Budgets were interpolated

Table 7.1 (con.)
Regional Emission Budgets and Confomity Estimates

8.0 Conclusions

The models and practices used to demonstrate transportation air quality conformity have been analyzed and discussed for the San Joaquin and Sacramento Valley regions. Of particular interest in this report are the activity data “links” between regional travel demand models and air quality emission models: vehicle trips, vehicle miles traveled and vehicle miles traveled by speed distribution.

Within the regional travel demand models, it is found that significant impact to these activity data can occur within the trip distribution and assignment steps, including any related feedback mechanisms. Travel model components which influence link speeds, such as friction factors, K-factors, and mode choice can also affect the activity data. The extent of the impact each of these items has on altering the resulting activity data depends largely on regional characteristics.

For many of the counties in the study area, the travel model activity data used by the emission models are subjected to extensive disaggregation. The disaggregation method, in turn, uses statewide data sources that are unrelated to the travel model.

The intent of this paper is to provide an understanding of the models used throughout the transportation conformity process, and how they all work together. Further research is needed to determine which of these areas can most effectively be improved, and what is the most efficient way of doing it.

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Appendix A
Conformity Survey

Air Quality Conformity Survey (v.3-07-99)

A. General question for <u>agencies responsible for federal conformity determinations</u>

Your Name [ ]

Your Agency [ ]

Today's Date [ ]

Which tasks of transportation demand modeling and regional conformity are completed in-house?
(e.g. all in-house; travel demand modeling contracted out, emission modeling done in-house; etc.)

☞

B. Travel Demand Model

1) What travel demand modeling software and version(s) do you currently use for your Conformity Assessments? *(e.g. MINUTP, EMMEZ)*
If you have recently changed software or versions, please note previous software/version(s) used.

☞

<u>Please reference your *current* travel demand model to answer the remaining questions in this section.</u>

2) Define modeling time periods and the number of assignment iterations used.

Modeling time periods	Number of assignment iterations
1.	**1.**

3) List trip purposes

1. Home-work
2.

4) Vehicle trip assignment

Trip assignment methodology: *("X" one)*

Capacity restraint	[ ]	Equilibrium	[ ]
Incremental	[ ]	Other	[ ]

How did you determine the number of iterations to use?

☞

5) Vehicle Types

Are there specific vehicle types identified in the model?	*Yes* ☐ *No* ☐ *If yes, please list:* **1.**
Do any trip purposes address particular vehicle types?	*Yes* ☐ *No* ☐ *If yes, please identify and explain.* ☞

6) Vehicle & link speeds

How are your free flow speeds defined?	☞
How do you compute the congested link speeds?	☞
Is there a floor to vehicle speeds that addresses very high V/C ratios?	*Yes* ☐ *No* ☐ *If yes, please indicate.* ☞
Are vehicle speeds processed differently by vehicle type? *(e.g. are HDV speeds on freeways lower than LDV speeds?)*	*Yes* ☐ *No* ☐ *If so, please explain.* ☞

7) Please list the road classifications used in your model.

Road Classification *(e.g. collector, freeway, etc.)*	Capacity Range *(veh/lane/hour)*	Speed Range *(Mph)*
1. Freeways **2.**	**1.**	**1.**

8) Feedback Process

Do you use a feedback process between the assignment and any other step in your travel demand model? *(please describe)*	☞

9) Feedback loop iterations

Where do the feedbacks occur? Trip assignment – trip distribution?	☞
What procedure is used to determine the number of loops?	☞

Do the number of loops change depending on the forecast year?	*Yes* ____ *No* ____ *If yes, how and why do they change?* ☞

10) Through traffic

How do you handle trips with O/D outside your modeling domain?	☞

11) Transit

Do you use a mode choice model?	*Yes* ____ *No* ____ *If so, please list the modes included.* **1.**
Do you have a procedure to account for the drive part of drive access transit trips in the vehicle assignment and congestion analysis?	*Yes* ____ *No* ____ *If so, please explain your procedure.* ☞

12) Congested conditions

How are high congestion levels handled? *(i.e. Do you spread the peak? Manually or through iterations?)*	☞

13) For the following improvements, we are trying to compile a set of modeling practices. How do you model the impacts of the following: *(e.g. adjust link speeds, increase capacity)*

Transit improvements	☞
Signal synchronization/ coordination	☞

14) Modeling capabilities

Do you have weekend modeling capabilities for your region?	*Yes* ____ *No* ____ *If yes, please elaborate on usage's, capabilities, and data sources.* ☞
Do you have access to weekend travel data for model inputs?	*Yes* ____ *No* ____ *If yes, please indicate data sources.* ☞

C. Travel Demand Model outputs vs. Emissions Model inputs

Are link speeds post-processed to the emissions model?	*Yes* ____ *No* _____ *If yes, please explain.* ☞
Are VMT outputs in the lowest and highest speed bins verified for reasonableness?	*Yes* ____ *No* _____ *If yes, what procedures are used?* ☞
Were there model validation criteria that were specifically included because of air quality analysis purposes?	*Yes* ____ *No* _____ *If yes, please indicate.* ☞
Do you perform *corridor-level* emissions analyses? *(This question is not limited to the Conformity analysis)*	*Yes* ____ *No* _____ *If yes, under what circumstances?* ☞

D. Motor Vehicle Emissions Model

1) What emissions modeling software and version(s) are currently used for your Conformity Assessments? *(e.g. EMFAC7F, BURDEN7G, DTIM)*
If you have recently changed software or versions, please note previous software/version(s) used.

☞

<u>Please reference your *current* emissions modeling procedures to answer the remaining questions in this section.</u>

2) Does you last conformity determination contain the following information?

- Current SIP budgets for all relevant pollutants (Ozone, PM-10, CO) Yes ☐ No ☐
- Emissions for all relevant pollutants for all modeled years. Yes ☐ No ☐

If so, could we get a copy of your most recent conformity document? Yes ☐ No ☐

3) Data Sources

Please indicate your major data sources for the following:

Vehicle types	☞
Vehicle class distributions	☞
Hourly temperatures	☞
Vehicle starts *(Source of hourly distribution)*	☞
Vehicle stops *(Source of hourly distribution)*	☞
Diurnal data *(Source of hourly distribution)*	☞

4) SIP Issues

Can you describe the problems you have encountered in identifying or calculating mobile source emission reduction credits contained in the SIP?	*Yes* ☐ *No* ☐ *If yes, how were they resolved?* ☞

5) TCM Issues

If applicable, how are TCM emission reductions calculated for conformity purposes?	☞
If applicable, how are TCM activities accounted for in your emissions calculation?	☞

E. Other Conformity-related issues

Has there been any difficulty meeting future year emission budgets as stated in the SIP?	*Yes* ____ *No* ____ *If yes how have you addressed this problem?* ☞

Please include any additional comments you may have in the space below.

☞

<u>Thank you for your time and participation in this survey!</u>

Control Factors for California SIP Measures* (Ozone)

On-road Mobile Sources

Fresno County **

1999

	HD Diesel Adjustments	*Enhanced Insp./Maint.*	*State Measures*	*Federal Measures*	***TOTAL FACTOR***
ROG/VOCs					
Light-duty Passenger and Truck	0.000	0.080	0.000	0.000	**0.080**
Medium-duty Trucks	0.000	0.080	0.000	0.000	**0.080**
Heavy-duty Gasoline Trucks	0.000	0.065	0.000	0.000	**0.065**
Heavy-duty Diesel Vehicles	0.366	0.000	0.000	0.000	**0.366**
Motorcycles	0.000	0.000	0.000	0.000	0.000
NOx					
Light-duty Passenger and Truck	0.000	0.072	0.000	0.000	**0.072**
Medium-duty Trucks	0.000	0.081	0.009	0.000	**0.090**
Heavy-duty Gasoline Trucks	0.000	0.081	0.010	0.000	**0.091**
Heavy-duty Diesel Vehicles	0.030	0.000	0.011	0.000	**0.041**
Motorcycles	0.000	0.000	0.000	0.000	0.000

* Apply these fractions to emissions estimates by vehicle class to calculate emissions reductions from state and federal measures not accounted for in EMFAC 7F.

** Assumes 74 percent application of enhanced I/M program (I/M96).

ARB/drt 3/20/96

Control Factors for California SIP Measures* (Ozone)

On-road Mobile Sources

Fresno County **

2002

	HD Diesel Adjustments	*Enhanced Insp./Maint.*	*State Measures*	*Federal Measures*	***TOTAL FACTOR***
ROG/VOCs					
Light-duty Passenger and Truck	0.000	0.116	0.000	0.000	**0.116**
Medium-duty Trucks	0.000	0.100	0.028	0.000	**0.128**
Heavy-duty Gasoline Trucks	0.000	0.086	0.026	0.000	**0.112**
Heavy-duty Diesel Vehicles	0.445	0.000	0.006	0.002	**0.453**
Motorcycles	0.000	0.000	0.000	0.000	0.000
NOx					
Light-duty Passenger and Truck	0.000	0.090	0.000	0.000	**0.090**
Medium-duty Trucks	0.000	0.081	0.096	0.000	**0.177**
Heavy-duty Gasoline Trucks	0.000	0.096	0.094	0.000	**0.190**
Heavy-duty Diesel Vehicles	0.084	0.000	0.035	0.000	**0.119**
Motorcycles	0.000	0.000	0.000	0.000	0.000

* Apply these fractions to emissions estimates by vehicle class to calculate emissions reductions from state and federal measures not accounted for in EMFAC 7F.

** Assumes 74 percent application of enhanced I/M program (I/M96).

ARB/drt 3/20/96

Control Factors for California SIP Measures* (Ozone)

On-road Mobile Sources

Fresno County **

2005

	HD Diesel Adjustments	*Enhanced Insp./Maint.*	*State Measures*	*Federal Measures*	***TOTAL FACTOR***
ROG/VOCs					
Light-duty Passenger and Truck	0.000	0.118	0.000	0.000	**0.118**
Medium-duty Trucks	0.000	0.093	0.078	0.000	**0.171**
Heavy-duty Gasoline Trucks	0.000	0.075	0.069	0.000	**0.144**
Heavy-duty Diesel Vehicles	0.484	0.000	0.048	0.014	**0.546**
Motorcycles	0.000	0.000	0.000	0.000	0.000
NOx					
Light-duty Passenger and Truck	0.000	0.093	0.000	0.000	**0.093**
Medium-duty Trucks	0.000	0.089	0.207	0.000	**0.296**
Heavy-duty Gasoline Trucks	0.000	0.089	0.207	0.000	**0.296**
Heavy-duty Diesel Vehicles	0.131	0.000	0.122	0.016	**0.269**
Motorcycles	0.000	0.000	0.000	0.000	0.000

* Apply these fractions to emissions estimates by vehicle class to calculate emissions reductions from state and federal measures not accounted for in EMFAC 7F.

** Assumes 74 percent application of enhanced I/M program (I/M96).

ARB/drt 3/20/96

Control Factors for California SIP Measures* (Ozone)

On-road Mobile Sources

Fresno County **

2008

	HD Diesel Adjustments	*Enhanced Insp./Maint.*	*State Measures*	*Federal Measures*	***TOTAL FACTOR***
ROG/VOCs					
Light-duty Passenger and Truck	0.000	0.135	0.000	0.000	**0.135**
Medium-duty Trucks	0.000	0.111	0.111	0.000	**0.222**
Heavy-duty Gasoline Trucks	0.000	0.117	0.094	0.000	**0.211**
Heavy-duty Diesel Vehicles	0.501	0.000	0.079	0.023	**0.603**
Motorcycles	0.000	0.000	0.000	0.000	0.000
NOx					
Light-duty Passenger and Truck	0.000	0.102	0.000	0.000	**0.102**
Medium-duty Trucks	0.000	0.111	0.260	0.000	**0.371**
Heavy-duty Gasoline Trucks	0.000	0.109	0.261	0.000	**0.370**
Heavy-duty Diesel Vehicles	0.141	0.000	0.178	0.034	**0.353**
Motorcycles	0.000	0.000	0.000	0.000	0.000

* Apply these fractions to emissions estimates by vehicle class to calculate emissions reductions from state and federal measures not accounted for in EMFAC 7F.

** Assumes 74 percent application of enhanced I/M program (I/M96).

ARB/drt 3/20/96

Control Factors for California SIP Measures* (Ozone)

On-road Mobile Sources

Fresno County **

2010

	HD Diesel Adjustments	*Enhanced Insp./Maint.*	*State Measures*	*Federal Measures*	***TOTAL FACTOR***
ROG/VOCs					
Light-duty Passenger and Truck	0.000	0.127	0.000	0.000	**0.127**
Medium-duty Trucks	0.000	0.087	0.164	0.000	**0.251**
Heavy-duty Gasoline Trucks	0.000	0.098	0.133	0.000	**0.231**
Heavy-duty Diesel Vehicles	0.517	0.000	0.120	0.034	**0.671**
Motorcycles	0.000	0.000	0.000	0.000	0.000
NOx					
Light-duty Passenger and Truck	0.000	0.097	0.000	0.000	**0.097**
Medium-duty Trucks	0.000	0.096	0.319	0.000	**0.415**
Heavy-duty Gasoline Trucks	0.000	0.096	0.319	0.000	**0.415**
Heavy-duty Diesel Vehicles	0.160	0.000	0.238	0.056	**0.454**
Motorcycles	0.000	0.000	0.000	0.000	0.000

* Apply these fractions to emissions estimates by vehicle class to calculate emissions reductions from state and federal measures not accounted for in EMFAC 7F.

** Assumes 74 percent application of enhanced I/M program (I/M96).

ARB/drt 3/20/96

Appendix D

San Joaquin Valley PM-10 Plan Conformity Worksheet

PM_{10} PLAN CONFORMITY WORKSHEET

Particulate matter of less than 10 microns aerodynamic diameter (PM-10) emissions from motor vehicles come from a number of sources including paved and unpaved roads, motor vehicle exhaust, and tire and brake wear. The following worksheet calculates the paved road motor vehicle emissions and sums them with the unpaved road emissions calculated by the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD), and the motor vehicle exhaust, tire and brake wear which are calculated in BURDEN.

Volatile organic compounds (VOC) and oxides of nitrogen (NO_x) are precursors of PM-10, meaning that after VOC and NO_x are emitted to the atmosphere they turn into PM-10 through chemical reaction. Thus, VOC and NO_x emissions from motor vehicles are also included in the APCD's PM-10 Attainment Demonstration Plan motor vehicle budgets. Both VOC and NO_x are calculated in BURDEN, but the emissions need to be adjusted for future control measures planned by the SJVUAPCD and the Air Resources Board (ARB). The Worksheet calculates the adjusted VOC and NO_x emissions from the values entered by the user from the BURDEN printouts (standard and comma-delimited file printouts). Finally, the Worksheet provides a summary of total motor vehicle PM-10, VOC and NO_x for comparison to the budgets established and submitted to the US Environmental Protection Agency in the APCD's PM-10 Attainment Demonstration Plan.

The PM-10 Plan Conformity Worksheet is made up of a number of tables which contain data and/or calculate emissions. Documentation on the data used in the Worksheet is contained in the attached ARB documents. The following explains the tables contained in the Worksheet and provides instructions for their use. The tables are numbered and these numbers are used throughout this reference document.

Table 1 – Paved Road PM-10 Emission Factor Calculation

In general, an emission factor relates the quantity (weight) of a pollutant emitted to a unit of the activity of the pollutant source. The emission factor for PM-10 emitted by a motor vehicle being driven upon a road is a function of the surface material loading (silt load) and the vehicle weight. Table 1 gives the silt loading factor in grams per square meter by facility class, and the average vehicle weight (data source: ARB). These data do not vary by county, thus are shaded which is the indicator for "fixed" data. Users should not have the need to change the fixed data in the Worksheet. In general, ARB allows the use of locally generated data over generalized, statewide data. The SJVUAPCD developed such local data for the "local" road class. Thus, Table 1 shows two types of "local" roads: local and local rural. Local rural is also known as "SJV Local." Local roads are those assumed to have curbs and gutters, and will generally be found in urban areas. As the name implies, local rurals are local roads located in rural areas and assumed to have no curbs or gutters. Curbs and gutters reduce the amount of PM-10 emissions to the atmosphere from vehicle traffic, thus the emission factor for SJV local roads is higher than for local "urban" roads.

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Table 2 – Travel Fraction and VMT by Facility Class

The User enters the county-specific travel fraction for each facility class from Table 14. Each year uses the same travel fractions developed from the 1993 data. Next, enter the total average daily Vehicle Miles Traveled (VMT) output from the MINUTP run for each model run year in the far right hand column of the appropriate row of Table 2. Please note that the value of VMT is the travel demand model output divided by one thousand. Daily VMT in thousand-miles is converted to annual VMT in million-miles in Table 2. The travel fractions by facility class entered into this table are used in Table 3 to calculate VMT by facility class. This Worksheet is not structured to use the VMT by facility class output from MINUTP, but this is a viable option in preparing one's conformity determination.

Table 3 – Paved Road PM-10 Emissions Without Control

Annual facility-class specific VMT is calculated in Table 3 from the travel fractions entered in Table 2. The source of the county-specific travel fraction data is the 1993 Caltrans HPMS data. This calculated value is then used with the facility-class specific, PM-10 emission factors calculated in Table 1 to calculate PM-10 in tons per year for each facility class. Facility class PM-10 is summed for an annual total in the far right column of the table. This calculation for PM-10 assumes that PM-10 emissions increase directly proportional to increasing VMT, but the Air Resources Board concluded for heavily traveled roads, such as freeways and major roads, this is not a realistic assumption. Therefore, PM-10 emissions for freeways and major roads are forecast based on the increase in centerline miles. For the PM-10 Attainment Plan budget calculations, the SJVUAPCD assumed that centerline miles would increase at a rate of 1.5 percent per year after 1993. The calculation of PM-10 emissions for freeways and major roads using the 1.5- percentage increase is performed in Table 4. The emissions of PM-10 for freeways and major roads are shown in Table 3 for informational purposes and can be used as a quality assurance check for other calculations. However, these freeway and major road PM-10 emissions are not used further in the calculation of total PM-10 from paved roads.

Table 4 – Paved Road PM-10 Emissions With Planned Control Measures

The PM-10 emissions in Table 3 are the emissions assuming there is no future control. Table 4 uses the calculated PM-10 emissions without control and applies the control factors for the PM-10 control measures delineated in the SJVUAPCD PM-10 Attainment Demonstration Plan (5/97). The total paved road PM-10 emissions for each year shown in Table 4 is then used in Table 11 for the calculation of total motor vehicle related PM-10 emissions to be compared to the Attainment Plan's budgets.

Table 5 – Summer VOC With and Without Control Measures

As previously discussed, VOC is a precursor to PM-10, thus emissions of VOC from motor vehicles must be accounted for in the calculation of total motor vehicle related PM-10. The source of VOC from motor vehicles is the fuel, but there are two mechanisms by which the emissions occur: evaporation and unburned fuel in the tailpipe exhaust. Because evaporation is directly related to the ambient temperature and because there are different summer and winter fuel blends, VOC emissions are calculated for both summer and winter and then summed. This worksheet uses the summer and winter VOC emissions, calculated in BURDEN, and adjusts them for control measures that will be implemented by the Air Resource Board. ARB's control measures are specific to the type of vehicle and to the specific process involved in either evaporative or exhaust emissions.

ARB quantifies four evaporative processes and two exhaust processes. The first evaporative process is emissions from the vehicle due to the diurnal temperature change. As the ambient temperature rises, the saturated fuel vapors expand and are displaced to the atmosphere from the vehicle fuel system. Similarly, as the ambient temperature drops, the fuel vapors cool and condense causing unsaturated air to be drawn into the fuel system. The unsaturated air drawn into the fuel tank becomes saturated with fuel via equilibrium setting up the cycle for the next day. Diurnal emissions have the units of grams per vehicle per hour. The second type of evaporative emissions occurs in the first hour after the vehicle engine is turned off. These are called hot soak emissions and are due to the high under-the-hood and fuel tank temperatures. Hot soak emissions have the units of grams per vehicle-start. Resting evaporative losses are quantified for the time when the vehicle is stationary and the ambient temperature is constant or dropping. Resting losses have the units of grams per vehicle per hour. The last type of evaporative losses is those that occur from the fuel system while the vehicle is in operation. These emissions are calculated in units of grams per mile. The two exhaust process emissions are calculated because the emission profile differs from the time of vehicle start to the stabilized running mode. The emissions during the first few minutes following start are generally higher since the engine and catalyst are not operating at their optimal temperature. Start exhaust emissions are calculated in the units of grams per start. Stabilized running exhaust emissions have the units of grams per mile. BURDEN calculates emissions in tons per day for each of these processes and vehicle type.

Because ARB's control measures are specific to the type of vehicle and to the specific emission processes, the conformity worksheet must use the emissions for the specific vehicle types and emissions processes that are targeted in the control measures. First, enter the VOC for All Vehicles from the Total VOC Emission line on the standard BURDEN summer printout. Next, one has to enter the BURDEN calculated VOC for five specific vehicle classes: medium-heavy-duty (MHD) diesel truck, heavy-heavy-duty (HHD) diesel truck, urban diesel bus (UBD), light-duty auto (LDA), and light-duty trucks (LDT) from the BURDEN summer comma-delimited file. For the three diesel vehicle types, one only enters the running exhaust (RE) VOC number from the comma-delimited file. For the two light-duty gasoline vehicle types, one needs to enter VOC emissions for diurnal (DI), running losses (RUNL), hot soak (HSK), resting losses (RSGL), and running exhaust (RE) from the BURDEN comma-delimited file printout. Control factors for these five vehicle classes are listed in Table 17a, but they do not vary by county. After one enters the summer VOC by vehicle class and emission process, and the total VOC for all vehicles by year into Table 5, it will output the summer VOC reflecting the future control measures.

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Table 6 – Winter VOC With and Without Control Measures

Similar to Table 5, enter the winter VOC for the five vehicle classes by emission process from the BURDEN comma-delimited file, and the total VOC for all vehicles from the standard BURDEN printout by year into Table 6 and it will output the winter VOC reflecting the future control measures.

Table 7 – Total VOC with Control Measures

Table 7 sums the adjusted summer and winter VOC for each year from Table 5 and 6. The sum is four twelfths (4/12) of the summer VOC and eight twelfths (8/12) of the winter VOC.

Table 8 – Summer NO_x With and Without Control Measures

NO_x like VOC is a precursor to PM-10, and NO_x emissions from motor vehicles must be accounted for in the calculation of total motor vehicle related PM-10. NO_x is known as a combustion contaminant meaning that it is an unwanted byproduct of fuel combustion in the motor vehicle engine. The quantity of NO_x formed during combustion is a function of temperature, so like VOC, NO_x is calculated for both summer and winter. In addition, like VOC, this worksheet uses the summer and winter NO_x emissions calculated in BURDEN and adjusts them for control measures that will be implemented by the Air Resource Board. ARB's control measures are specific to the type of vehicle. Therefore, one needs to enter the NO_x value from the winter BURDEN Total NO_x Emission line for the three vehicle classes including medium-duty diesel truck, heavy-duty diesel truck, and urban diesel bus. Control factors for these three vehicle classes are listed in Table 17b, but they do not vary by county. Next, enter the NO_x value from the winter BURDEN Total NO_x Emission line for All Vehicles. After entering both the summer total NO_x by vehicle class and the total NO_x for all vehicles by year into Table 8, it will output the summer NO_x reflecting the future control measures.

Table 9 – Winter NO_x With and Without Control Measures

Similar to Table 8, enter both the winter total NO_x by vehicle class and the total NO_x for all vehicles by year into Table 9 and it will output the winter NO_x reflecting the future control measures.

Table 10 – Total NO_x with Control Measures

Table 10 sums the adjusted summer and winter NO_x for each year from Table 8 and 9. The sum is four twelfths (4/12) of the summer NO_x and eight twelfths (8/12) of the winter NO_x.

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Table 11 – Total PM-10 – Paved and Unpaved Roads, Exhaust, and Tire and Brake Wear Emissions

Table 11 sums motor vehicle related PM-10 by year for comparison to the motor vehicle PM-10 budgets in SJVUAPCD's PM-10 Attainment Demonstration Plan. Each county specific PM-10 budget is listed in Table 15, and one must enter the appropriate budget listed in Table 15 into Table 11 in the column labeled Budget. Enter the county-specific unpaved road PM-10 emissions from Table 18 into the column labeled Unpaved Roads. Enter the total PM-10 emissions for exhaust, tire-wear, and brake-wear from either the summer or the winter BURDEN output (value should be the same for summer and winter) for the appropriate year into the column labeled 7G. The total PM-10 for paved roads from Table 4 is listed by the worksheet in the column labeled Paved Roads. The difference between the calculated PM-10 emissions for the conformity determination year and the budgets from the PM-10 Attainment Demonstration Plan are shown in the far right column of Table 11 after entering the appropriate data in the table's other columns.

Table 12 – Total VOC – Exhaust and Evaporative Emissions

Table 12 is used for comparison of the motor vehicle VOC budgets in SJVUAPCD's PM-10 Attainment Demonstration Plan to the VOC value calculated for each conformity determination year. Each county specific VOC budget is listed in Table 15, and one must enter the appropriate budget listed in Table 15 into Table 12 in the column labeled Budget. The total (adjusted) VOC from motor vehicles from Table 7 is listed by the worksheet in the column labeled TPD (tons per day) VOC. The difference between the calculated VOC emissions for the conformity determination year and the VOC budgets from the PM-10 Attainment Demonstration Plan is shown in the far right column of Table 12 after entering the appropriate budget data.

Table 13 – Total NO_x – Exhaust Emissions

Table 13 is used for comparison of the motor vehicle NO_x budgets in SJVUAPCD's PM-10 Attainment Demonstration Plan to the NO_x value calculated for each conformity determination year. Each county specific NO_x budget is listed in Table 15, and one must enter the appropriate budget listed in Table 15 into Table 13 in the column labeled Budget. The total (adjusted) NO_x from motor vehicles from Table 10 is listed by the worksheet in the column labeled TPD (tons per day) NO_x. The difference between the calculated NO_x emissions for the conformity determination year and the NO_x budgets from the PM-10 Attainment Demonstration Plan is shown in the far right column of Table 13 after entering the appropriate budget data.

Table 14 – 1993 HPMS Travel Fractions

Table 14 shows the 1993 HPMS travel fractions for each county. These data are used in Table 2 - Travel Fraction and VMT by Facility Class. The travel fractions were developed by the Air

Resource Board and their derivation is described in the attached documentation obtained from ARB.

Table 15 – PM-10 Attainment Demonstration Plan Budgets by County

Table 15 lists the PM-10 Attainment Demonstration Plan's budgets for PM-10, VOC and NO_x by county. This table data is used in Tables 11, 12, and 13.

Table 16 – SJVUAPCD PM-10 Control Factors

Table 16 lists the PM-10 control factors for the paved and unpaved road control measure (Rule 8060) in the SJVUAPCD's PM-10 Attainment Demonstration Plan.

Table 17a and 17b – ARB VOC and NO_x Control Factors

Table 17a lists the VOC control factors for medium-heavy-duty diesel trucks, heavy-heavy-duty diesel trucks, urban diesel buses, light-duty autos, and light-duty trucks. Table 17b lists the NO_x control factors for medium-heavy-duty diesel trucks, heavy-heavy-duty diesel trucks, and urban diesel buses. These control factors are from the State's Ozone State Implementation Plan. These tables' data is used in Tables 5, 6, 7 and 8.

Table 18 – Unpaved Road Emissions by County

Table 18 lists the PM-10 emissions for unpaved roads for each of the eight counties from the SJVUAPCD's PM-10 Attainment Demonstration Plan. The unpaved roads PM-10 emissions are not dependent on VMT.