

The California Department of Transportation / Air Resources Board Modeling Program (CAMP): New Research to Improve Speed Correction Factors and Mobile Source Emissions Modeling

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ABSTRACT

The California Department of Transportation (Caltrans), the California Air Resources Board (ARB), and the University of California, Davis have worked over the past three years to improve mobile source emissions inventory modeling. The research is motivated by two historical problems that exist in California, that of estimating facility-specific (e.g., freeway) emissions using tools developed to represent emissions from entire trips, and that of determining conformity by comparing air agency emissions budgets created with one model (BURDEN) to transportation agency emissions estimates created with a separate model (DTIM). This paper reports on the work scope, progress to date, and status of the new modeling tools. Future papers will describe specific elements of the program in more detail. One of the project's major accomplishments to date includes the collection of over 260 hours of target-vehicle driving behavior data. Data were collected in large metropolitan areas (Los Angeles, San Francisco), a medium-sized area (Sacramento), and more rural communities (San Joaquin Valley). In comparison, mobile source emissions modeling tools currently used in California include emission factors based on 15 hours of target-vehicle driving data collected in Los Angeles during 1992 ("LA92" data set). The CAMP project expands the fundamental data available to evaluate driving behavior and construct mobile source emissions factors, a contribution with national implications.

INTRODUCTION

Historical Background

For six months during 1992, California's transportation planning community was in a state of high anxiety. In May 1992, the California Air Resources Board (ARB) formally announced the release of a new version of its mobile source emissions modeling tool, EMFAC. Later referred to as EMFAC7EP-SCF1, the updated modeling tool included new speed correction factors (SCFs) that altered the fundamental thinking about the relationship between vehicle speed and emissions. Since the early 1970s, the transportation planning community had relied on the understanding that as speeds increased, emissions generally decreased. The correlation between decreasing emissions and increasing speeds enabled the transportation community to build roads, improve highways, and generally improve traffic

flow and relieve congestion while working in harmony with air quality goals. ARB's new SCFs removed the cornerstone upon which Caltrans had built its transportation planning assumptions.

EMFAC versions prior to 7EP-SCF1 incorporated SCFs that predicted minimum emissions at approximately 55 mph for hydrocarbon (HC) and carbon monoxide (CO), and approximately 40 mph for oxides of nitrogen (NO_x). EMFAC7EP-SCF1 changed the optimum vehicle operating speeds to approximately 30 mph for HC and 35 mph for CO. The new SCFs predicted minimum NO_x emissions would occur at approximately 20 mph instead of 40 mph (Caltrans, 1992). The implications of the new SCFs were substantial:

“Any transportation action which has the effect of increasing average operating speed on a highway facility from the 20 to 35 mph range to a higher speed, likely will be shown to have a negative effect on air quality. This increase in operating speed could result from either increases in capacity of a highway facility, or from a non-highway action which has the effect of removing vehicles from highway(s), thereby increasing the speeds of the remaining vehicles. **In ozone and CO nonattainment areas, such projects are not likely to be able to be approved unless they are accompanied with a substantial reduction in VMT.”** [*emphasis added*]¹

Not only did the new SCFs create concern because of their potential to disrupt transportation planning, but Caltrans environmental staff also believed the new SCFs defied traffic engineering principles. Caltrans believed that from an engineering perspective, traffic flow below 35 mph generally begins to experience stop-and-go conditions, which would presumably increase emissions.² What ensued following the release of EMFAC7EP-SCF1 was a full-scale effort by Caltrans and ARB to technically review the underlying data contributing to the new SCFs.

Following six months of intensive review and data analyses, ARB abandoned EMFAC7EP-SCF1 and revised, once again, the EMFAC SCFs. In November 1992, ARB formally released new correction factors in a model version known as EMFAC7EP-SCF2. The new SCFs conformed more closely to traditionally held views concerning speed and emissions relationships. The updated correction factors established the minimum emissions point at approximately 50 mph for HC and CO and approximately 35 mph for NO_x.³ Although the immediate crisis had passed, the transportation community was now fully engaged in the SCF development process. Caltrans had come away from the 1992 modeling crisis with a deeper understanding of how EMFAC modeled the relationship between vehicle speed and emissions. The result was dissatisfaction on the part of the transportation community with the way EMFAC predicted emissions from specific transportation facilities such as freeways or arterials.

Defining the Need for Facility-Specific Speed Correction Factors

EMFAC7EP-SCF2's SCFs were derived from dynamometer-based emissions data gathered from vehicles driven on driving cycles designed to represent trips with various average speeds. ARB retains the same conceptual trip-based approach in its latest model, EMFAC2000.⁴ Each cycle includes a portion of local road driving and arterial and freeway driving. The trip-based approach is oriented towards developing regional emissions inventories, in fulfillment of ARB's mandate. Caltrans, however, has a need to evaluate emission changes that occur due to transportation projects affecting specific road segments or links. SCFs created to represent trips are not directly applicable to individual road segments.⁵ For example, an entire trip with an average speed of 45 mph might involve various stop-and-go travel activity on surface streets, idle time at stop lights, and higher-speed driving on a freeway or major arterial. In comparison, a vehicle averaging 45 mph on a freeway may experience more uniform driving conditions with less stop-and-go behavior. Although both activities involve travel

activity averaging 45 mph, emissions from the freeway-specific behavior will likely differ from those of the 45-mph trip.

At the conclusion of the 1992 events surrounding the release of ARB's updated SCFs, Caltrans determined that longer-term research was necessary to support creation of SCFs specific to individual transportation facilities and that it was essential to collect facility-specific data that could be used to construct facility-specific driving cycles and, ultimately, to use the cycles to create facility-specific SCFs.

Recent Examples of Interest in the Speed and Emissions Relationship

Caltrans is not unique in its interest to better understand the relationship between vehicle speeds and emissions. The speed-to-emissions relationship is a central component of virtually all motor vehicle emissions analyses, and federal conformity requirements call for the use of the latest available planning assumptions regarding vehicle speed,

“Since emission estimates are sensitive to vehicle speed, EPA and DOT recommend that areas using network-based travel models compare the speeds estimated in the validation year with speeds empirically observed during the peak and off-peak periods. The significant sensitivity of emissions to highway speeds emphasizes the need to monitor and maintain the ability of the transportation model to provide accurate speed estimates. Nonattainment and maintenance areas using network-based travel models are encouraged to establish criteria for updating the observed speed data that are used to validate the speeds predicted by the transportation model. The criteria should identify the schedule on which speed data will be collected given the pace of growth in the urban area, the magnitude of changes to the highway system, and any fundamental changes in speed-related conditions such as the change in Federal law on speed limits”.⁶

The Houston-Galveston area of Texas provides a recent example of how important speed-to-emissions assumptions have become with respect to air quality planning. The Texas Natural Resource Conservation Commission (TNRCC), using the MOBILE5 emissions modeling tool, prepared an ozone state implementation plan (SIP) for the Houston-Galveston area that included a requirement to reduce vehicle speeds to 55 mph. TNRCC estimated a 2.3% VOC reduction and a 6.9% NO_x reduction from on-road mobile sources when requiring speed limits not to exceed 55 mph.⁷ The speed limit control strategy was a critical element in Houston's planning to reduce NO_x emissions. In April 2000, TNRCC estimated that an additional 118 tpd of NO_x controls was needed, beyond existing control measures, to demonstrate attainment of the ozone standard in 2007.⁸ TNRCC estimated that 12.18 tpd of the needed 118 tpd of NO_x reduction could be achieved by implementing a 55 mph speed limit.⁸ In November 2001, the U.S. Environmental Protection Agency (EPA) approved the speed limit strategy as part of the overall Houston-Galveston ozone SIP.⁹ Central to the underlying assumptions concerning the emissions reductions included in the Houston-Galveston SIP are the SCFs included in EPA's MOBILE model. The SCFs help predict the speed-to-emissions relationship, and in the case of MOBILE5, as with recent versions of EMFAC in California, the SCFs predict significantly higher emissions as speeds exceed 55 mph.

What is particularly interesting about the Houston-Galveston example is that the region's ozone SIP includes the effects of speed limit controls as modeled with *trip-based* SCFs included in MOBILE5. In January 2002, EPA released MOBILE6, an updated model, which includes *facility-specific* SCFs. Much as the environmental program staff at Caltrans had theorized, the use of facility-specific SCFs

appears to have reduced the predicted per-mile emissions from light-duty vehicles operating at higher speeds (e.g., above 60 mph).¹⁰

Creation of the Caltrans/ARB Modeling Program (CAMP)

As early as July 1992, Caltrans perceived the need for "...a cooperative review of the present and proposed speed correction factors by a broad based inter-disciplinary task force involving ARB, EPA, FHWA, Caltrans, and representatives of the MPOs and the local air districts." Caltrans was specifically interested in evaluating the emission factors used to represent freeways, and, if necessary, to begin "...development of [speed correction] factors particular to the types of facilities carrying the bulk of the vehicle miles traveled in California".¹¹ Caltrans later acknowledged it might take "...two or more years to collect the data necessary to develop factors which are comparable to facility types and actual operations".¹²

By January 1998, Caltrans and ARB had developed and signed a Memorandum of Understanding (MOU) to act as co-lead agencies in two special projects to (a) improve speed correction factors and (b) improve modeling to support implementation of the new factors.¹³ By the 1998-1999 fiscal year, the California State legislature had added approximately three million dollars to the Caltrans budget to implement the MOU.

Caltrans requested that the University of California, Davis (UCD) organize and facilitate a multi-agency work group that could oversee the research needed to implement the MOU. UCD was also to serve as a technical advisor for both scoping and analysis issues as they arose. In October 1998, UCD facilitated the first meeting of the Caltrans/ARB Modeling Program (CAMP) work group. Invited participants included representatives from the Bay Area Air Quality Management District, the San Joaquin Valley Unified Air Pollution Control District, the Southern California Association of Governments (the metropolitan planning organization, or MPO, for the Los Angeles area), the Sacramento Area Council of Governments (the MPO for the Sacramento area), Caltrans, and ARB. As the CAMP work group proceeded to design and implement research tasks, UCD also informally kept representatives from EPA and FHWA apprised of the work group's efforts. CAMP goals mirrored the objectives outlined in the multi-agency MOU: (a) improve speed correction factors and (b) improve the linkage between travel demand models and emissions models.¹⁴

At the heart of the CAMP research program was the need to collect real-world driving behavior data that was specific to transportation facility type. Caltrans especially wanted to be able to represent the driving behavior, and resulting emissions, that occurred on freeways and major arterials operating under a broad range of traffic conditions. Caltrans requested that the study team collect data to represent travel behavior for the each of the "levels of service" (LOS) that traffic engineers used to characterize traffic conditions. LOS categories are defined by the Transportation Research Board (TRB) as either A, B, C, D, E or F, with LOS A equivalent to free-flow conditions and LOS F equivalent to heavily congested conditions.¹⁵

ARB wanted to use the CAMP project to update the trip-based travel behavior data used to develop regional-scale emission inventories. During 1992, ARB collected trip-based driving behavior data in the Los Angeles area and has since used that data to construct driving cycles to represent California driving behavior. Much of the 1992 data collected, however, was based on "chase vehicle" operations, rather than on observations of real-world vehicles.¹⁶ ARB hoped to use CAMP to augment its existing data set and, in particular, to improve the data collected at "trip ends," meaning at the start and end of trips representative of travel in California regions.

Over a period spanning several months and multiple meetings, the CAMP work group identified eight tasks necessary to successfully implement the ARB/Caltrans MOU:

- Task 1. Completion of scoping studies to define data collection considerations for driving cycle and SCF development and to assess how transportation and air quality agencies use existing modeling tools throughout the transportation conformity process.

Results from Task 1 were then used to guide development of later research goals and work scopes.

- Task 2. Development of a statistically based sampling methodology to insure that the collected field data adequately represented transportation facilities and operating conditions (LOS).
- Task 3. Implementation of a field program to gather facility-specific and trip-based driving behavior.
- Task 4. Collection of trip-end travel behavior via vehicles instrumented with global positioning system (GPS) units.
- Task 5. Development of driving cycles based on the collected travel behavior data.
- Task 6. Completion of dynamometer testing to obtain tailpipe emissions data based on the new driving cycles.
- Task 7. Development of new speed correction factors to represent facility-based operations.
- Task 8. Development and implementation of an improved modeling platform to create consistent emissions estimates regardless of whether trip- or segment-based data are used as activity inputs.

Completion of each task involves interagency consultation over task objectives, work scope content, budget, consultant selection, draft work product review, mid-course corrections, and final work product preparation. This paper reports on the work scope, progress to date, and status of the new modeling tools; future papers will describe specific elements of the program in more detail.

ACCOMPLISHMENTS TO DATE

Progress includes completion of scoping studies, data collection, and a variety of related activities. Table 1 includes a listing of CAMP-related reports and publications to date.

Scoping Studies

During 1998 and 1999, UCD completed scoping studies that guided the CAMP work group's later efforts. Important findings resulted.^{5,17,18}

- Freeway driving patterns for LOS A through C conditions do not differ greatly from LOS D but do differ from LOS E and LOS F. For arterials, driving patterns for LOS A-C are slightly different from D and dramatically different from LOS E and LOS F.¹⁷
- Chase car studies should use improved protocols for sampling and route selection procedures, lane choice during data collection, treatment of missing data, target-vehicle selection, laser tracking, and LOS determination.¹⁷

- Driving behavior differences exist among regions and facility type, and data collection would improve if sampling involved multiple geographic areas.^{17,18}
- GPS data collection protocols would need to overcome sampling biases and the influence of the instruments on driver behavior.¹⁷
- California regions are inconsistent in their use of modeling tools to prepare mobile source inventories (e.g., Sacramento uses DTIM, and San Joaquin Valley uses BURDEN).⁵

Data Collection

The CAMP work group decided on a strategy to obtain driving behavior samples across the diverse range of California's geographic areas. Ultimately, data collection encompassed the fast-growing rural areas of the state's central valley (Stanislaus County in the San Joaquin Valley), a mid-sized metropolitan area (Sacramento), and large urbanized areas in both northern and southern California (San Francisco and Los Angeles). The geographic areas selected for study represent approximately 80% of the vehicle miles traveled (VMT) within California (see Table 2). Chase cars equipped with laser-based tracking tools and GPS units were deployed to randomly select "target" vehicles and to observe their driving behavior. The chase cars were driven on pre-determined routes selected to best represent driving activity in the metropolitan area. The route-based driving strategy was created to meet both ARB's trip-based data collection goals, and Caltrans' segment-based data collection goals. To minimize past problems with previous chase car studies, the CAMP work group implemented a variety of protocol improvements for chase car operations and agreed to use only "lock-on" data representing real-world target-vehicle driving behavior (i.e., data gathered by the chase car once it was "locked onto" a randomly selected target vehicle). The decision to use only lock-on data was a departure from ARB's 1992 field program (LA92), which augmented target-vehicle data with data representing the chase vehicle's operations.

Sample Size Goals

Sample size goals were determined by (1) identifying a travel activity metric measured by the chase car that would serve as a surrogate for vehicle emissions and (2) identifying minimum sample size requirements for measuring that metric. The CAMP work group selected *road power* as an observed metric closely related to vehicle emissions and then used data from past chase vehicle studies to quantify the variance observed in road power measurements. The CAMP work group was then able to determine optimum minimum and maximum lock-on time periods for tracking individual vehicles, as well as to determine proxy sample sizes for overall lock-on data needed to represent driving in a metropolitan area and by individual facilities (e.g., freeways, arterials).

The primary sampling objectives were defined as the need to (a) collect approximately 50 hours of lock-on target-vehicle data for each metropolitan area and (b) obtain lock-on data for individual target vehicles that were at least 20 seconds and no more than 100 seconds in duration. The road power variance (RPV) was measured for the data collected, and statistical analyses conducted to determine margins of error for the RPV observations. Initially, the sampling goals were drafted by analyzing data from prior (pre-CAMP) chase-vehicle work in Sacramento. The prior Sacramento data was used to approximate the expected RPV by facility type and to develop proxy sampling objectives. Once CAMP data collection proceeded, the CAMP work group quality-assured the study results by conducting mid-course evaluations of actual RPV and other statistics observed during the CAMP study to refine the remainder of the data collection effort for each metropolitan area. Descriptions of the sampling effort are available in related reports.¹⁹

Field Program

Data collection began in February and continued through June 2000 in the Sacramento, San Francisco, and San Joaquin Valley areas, and took place from August through September 2000 in Los Angeles. Supplemental segment-based driving occurred in Los Angeles during November 2001. Table 2 summarizes the data collected.

As documented in Table 2, the CAMP effort has collected approximately 264 hours of lock-on target-vehicle driving data. In comparison, the LA92 data collection effort (used by ARB as the foundation for developing EMFAC's emission factors) yielded approximately 28 hours of data, 15 hours of which were from target-vehicle operations, with the remaining 13 hours drawn from chase-vehicle operations.¹⁶ The LA92 data collection program gathered data only from Los Angeles, in contrast to CAMP's geographically diverse data collection effort.

Related Activities

In tandem with the CAMP data collection program, UCD has overseen several related efforts designed to complement the data collection effort and provide insights into cycle development and expected SCFs.

Quality Assurance Efforts to Improve Chase Car Deployment

During 1999, Sierra Research was directed to conduct a chase-car exercise to test the ability of the laser-guided tracking system to accurately observe target-vehicle speed. Sierra deployed two chase vehicles, one to act as a "target" and the second to follow and track the target vehicle. The "target" chase vehicle operated on cruise control at 65 mph and used specialized on-board equipment to measure its vehicle speed (the specialized equipment is more accurate than original-equipment speedometer readings). The second chase vehicle tracked the target and measured its travel behavior. Sierra then compared the chase-vehicle measurements to the "actual" speeds measured by the target vehicle. Results showed that the chase vehicle locked onto the target for four minutes and 20 seconds, recording 260 speed data values (one for each second). Of the 260 values, 72% were within 0.5 mph of the actual speed as measured by the target vehicle. The range of difference between actual and measured was from -1.68 mph to +1.34 mph. The mean difference was -0.13 mph and the median difference was -0.12 mph. Sierra reported that the equipment in each vehicle was probably accurate to within +/- 0.5 mph.²⁰

Pilot Dynamometer Testing

During the fall and summer of 2001, testing was completed on three late-model vehicles, a 2001 Toyota Camry, a 2001 Pontiac Grand Prix, and a 2001 Ford Sable. The purpose of the dynamometer work was to run a brief experiment testing the hypothesis that a driving cycle designed to mimic steady-state, high-speed, freeway driving results in relatively low emissions compared to the emissions observed from trip-based driving cycles. Testing was conducted on 12 driving cycles: two trip-based cycles used by ARB to support SCF development for EMFAC 2000, two facility-based cycles used by EPA to support SCF development for MOBILE6, and eight steady-state (constant speed) cycles that matched the average speeds of the trip- and facility-based cycles. The steady-state driving produced fewer emissions on a gram-per-mile basis than the driving simulated using other cycles²¹ (upcoming CAMP-related publications will provide further details on the test results).

Defining LOS Conditions With Freeway Loop Data

During the fall of 2001, UCD, working with University of California, Berkeley, and Dowling and Associates, used Los Angeles freeway loop detector data to identify freeway segments operating under high-speed, steady-state conditions. The work effort pioneered the use of loop data to estimate real-time LOS conditions.²² Results were later used by the CAMP work group to create a deployment strategy for collecting supplemental travel behavior data.

Development of a New Modeling Tool to Prepare Mobile Source Emissions

During 2001 and continuing into 2002, UCD worked to develop a methodology for producing gridded regional emission inventories. Current methods, both BURDEN 2001 and DTIM4, incorrectly require that link-level transportation activity be combined with trip-based emission factors. Since one of the main purposes of the CAMP project is to produce facility-specific emission factors, UCD proposed a modeling platform that could be described as an enhanced version of a DTIM4-style platform. The enhanced model would be coded to work with emission factors that were a function not only of speed, but link speed, LOS, and facility type. Significant progress has been made on model development.

NEXT STEPS

Cycle Development

As of February 2002, quality assurance work is underway on the field data, and cycle development is expected to proceed in early spring 2002. Initially, two sets of driving cycles will be developed, based on separate methodologies: (1) the methodology created by Sierra Research and employed to develop the driving cycles currently in EMFAC 2000 and MOBILE6²³ and (2) a methodology created by UCD to improve cycle development by clustering and replicating activity by modal events (accelerations and decelerations) rather than clustering on trip and facility characteristics (e.g., when vehicles enter or leave a freeway).²⁴

Dynamometer Testing

Once cycle development is complete, the CAMP program will turn to dynamometer testing by mid- to late-2002. Current plans and budget allow for approximately 1,700 to 2,200 dynamometer tests spread over approximately 12 to 15 driving cycles. The test fleet will consist of approximately 60 vehicles: 30 later-model (1992 or newer) multi-point fuel-injected (MFI) vehicles; 10 1986- to 1991-era vehicles with older MFI and throttle-body fuel injected (TBI) emission control technologies; 10 TBI vehicles dating from the early- to mid-1980s; and 10 carbureted vehicles. All vehicles are expected to represent "normal" emitters (i.e., no gross-polluting vehicles will be included in the study). To provide for some redundancy and quality-control capability, identical testing is scheduled to occur at separate dynamometer facilities operated by Sierra Research and the Clean Air Vehicle Technology Center.

SCF Development

Dynamometer test results will be quality assured, and SCFs developed. Based on CAMP findings to date, there is an identified need to develop SCFs that represent different facilities *and* geographic regions.²⁵ Budget limitations will likely require the CAMP work group to limit SCF development to freeway-specific applications and constrain the ability to develop SCFs specific to multiple regions. The freeway SCFs will likely be constructed to represent average travel behavior

indicative of activity throughout California, or activity representative of the metropolitan area(s) where the bulk of the state's driving occurs (i.e., southern California). Additional SCF development, for other regions or facility types, may proceed as funding becomes available. The CAMP work group recognizes the longer-term importance of completing both freeway *and* arterial SCFs to improve conformity analyses. The CAMP work group will likely finalize its SCF development strategy by the time dynamometer testing has been completed.

Model Development and Implementation

Once SCF development is complete, the new correction factors will be included in the new model platform currently under development. Training and implementation will follow model completion.

KEY CHALLENGES

Given the project's scope and the numerous agencies involved, many challenges have been addressed during each research stage. This discussion shares examples of the more important hurdles that have challenged the working group during the work to date and provides insights into managing multi-agency research efforts involving partners with different, and at times conflicting, research goals.

From an early point in the multi-agency process, it was apparent the different missions served by ARB and Caltrans posed a challenge to work group participants. One of the earliest difficulties was reaching consensus on whether to collect trip- or segment-based driving data. Although both approaches yield information on segments, repeatability on the same facility is not directly addressed in the trip approach. ARB's active participation in the CAMP research effort has been at least partially premised on the ability to expand ARB's understanding of trip-based travel activity. Caltrans, however, has been primarily interested in facility-based travel behavior although the Department of Transportation is philosophically supportive of improving mobile emission inventories in general. A compromise was reached to carefully design the data collection effort to utilize trip-based chase car driving, but to insure that facility-specific (especially freeway) data collection was robust. The use of statistically based sample size goals enabled ARB and Caltrans to reach agreement on when adequate trip- or segment-based driving had been completed. Typically, at about the 50% data collection point, both agencies agreed that enough trip-based data had been gathered to allow remaining chase-car work to focus mostly on gathering additional data on specific facility types (freeways, arterials). This approach proved especially valuable in Los Angeles when trip-based driving goals were realized after only 50% of the driving had been completed, and the remaining resources were shifted entirely to freeway-only driving.

A second challenge emerged as data collection methodologies were discussed. ARB, together with Sierra Research, had worked in past years to deploy chase vehicles as the tool of choice to obtain travel behavior data. Caltrans had also sponsored chase-vehicle work but had technical problems with previous study protocols, including the combined use of target and chase-vehicle information and the assignment of LOS. Recent technological advances offered the opportunity to collect data via instrumented vehicles and deployment of global positioning system (GPS) units. After extensive debate, the CAMP work group decided to forego the use of new technology and to use existing chase vehicle methods with improved data management protocols. As a result, UCD worked closely with the CAMP work group and several consulting organizations to identify and overcome six major concerns with previous studies:

1. Improper identification of LOS by the chase vehicle team.
2. Lower-than acceptable quantities of target-vehicle lock-on data.
3. Use of chase-vehicle driving behavior data to supplement target-vehicle data.
4. Lack of robust trip-end data collection.
5. A need to improve the ability of the driving routes selected to represent regional travel.
6. A need to insure that the chase vehicle was not mistaken for a law enforcement vehicle and, therefore, result in altered travel behavior by drivers of target vehicles.

A third challenge involved selection of the geographic regions to be sampled. Initially, the CAMP work group determined that the study should collect data outside the Los Angeles region. CAMP participants based this determination on two findings: (1) ARB traditionally collects field data in Los Angeles, and the CAMP resources should be devoted to collecting data in regions that would otherwise fail to be sampled; and (2) scoping study results indicated a need to gather data from a diverse collection of regions. As data collection began, however, Caltrans participants decided that the study would not be complete without representing travel from the Los Angeles area. Rather than disrupting the consensus selection of areas already identified for study (Sacramento, San Joaquin Valley, and San Francisco), Caltrans made the necessary resources available to obtain driving data from Los Angeles in addition to the areas selected by the work group as a whole.

Fourth, the CAMP effort encountered a significant challenge when Caltrans participants determined partway through the data collection effort that LOS was not being resolved at the appropriate level of detail. Prior to deploying the chase vehicles, the CAMP work group reviewed and approved LOS determination procedures that would allow the data to be categorized as being approximately LOS A-C, D-E, or F, based on an indirect assessment of LOS that compared observed travel speeds to posted speed limits. Later review by Caltrans management determined that they needed a partitioning of the A through C LOSs. Subsequently, the chase vehicle was deployed in Los Angeles to gather freeway-specific data that could definitively be linked to specific LOS categories, especially LOS A (thought to be higher-speed, free-flow travel).

These difficulties are shared to provide insights about the challenges of designing and implementing a multi-year, multi-agency research project. Fieldwork is, by definition, somewhat unpredictable in its outcome. The CAMP work group has labored to methodically design a data collection program that meets the diverse needs of its partner agencies, and to overcome obstacles that are by nature inevitable during a project of this magnitude. Participants from all agencies, and especially from ARB, Caltrans, and SACOG, have provided consistent and insightful technical support throughout the three-plus years of the CAMP effort to date. As a result, and despite the many challenges addressed, the CAMP program has collected what is probably the most robust current view of U.S. on-road light-duty vehicle travel behavior. Data is now in hand to definitively establish facility-specific SCFs and to offer transportation and air quality planners a new modeling framework that will better integrate emissions estimation across the transportation and air quality planning divide.

CONCLUSIONS

The collaborative research program, CAMP, has evolved over the past several years into a multi-agency work group with three main goals: (1) collect state-of-the-art driving behavior data representative of driving across four major California regions and various road types; (2) develop facility-specific speed correction factors based on the driving data, facility-specific driving cycles, and dynamometer testing; and (3) incorporate the new speed correction factors into a new modeling

platform that allows transportation and air quality planners to create a variety of spatially consistent emission inventories.

The CAMP program has collected over 260 hours of lock-on target-vehicle travel-behavior data. The collected travel-behavior data represents an 18-fold increase in the target-vehicle data collected to support past emission inventory model development and includes statistically robust sampling across a diverse array of geographic regions and transportation facilities. The data will likely be available by late 2002 or early 2003 to support other research efforts. Significant progress has been made developing a new modeling tool that should eliminate past inconsistencies between mobile source emission inventories prepared in support of air quality plans, and mobile source emission inventories prepared to complete conformity analyses. To support facility-specific SCF development, the CAMP effort has resulted in or will soon produce

- Improved chase car driving protocols.
- Development of advanced driving cycle development methodologies.
- New quality assurance techniques for chase-car deployment.
- Insights concerning emissions related to free-flow travel at high speeds.
- Protocols to utilize freeway loop detector data to measure real-time LOS.
- Improved SCFs.

Barring unforeseen budgetary problems (a real threat in the current California financial climate), cycle development, dynamometer testing, and creation of facility-specific SCFs should be complete within the coming year.

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KEY WORDS

speed correction factors, on-road mobile source emissions modeling, travel behavior

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DISCLAIMER

The opinions expressed are those of the authors alone.

TABLES

Table 1. Bibliography of CAMP-related reports and publications as of February 2002.

Scoping Studies

- Speed Correction Curves Scoping Study.²⁶
- Changing Speed-VMT Distributions: The Effects on Emissions Inventories and Conformity.¹⁸
- Data Collection for Driving Cycle Development.²⁷
- Validity in Chase Car Data: Issues of Variability and Implications for Construction of Emissions Cycles.¹⁷
- Transportation Air Quality Conformity Modeling in Sacramento and San Joaquin Valley.²⁸
- How VMT-Speed Distributions Can Affect Mobile Emissions Inventory Modeling.⁵
- Spatial Applicability of Emission Factors for Modeling Mobile Emissions.²⁵

Sample Size Goals

- Speed Correction Factor Improvement Study, Estimating Sample Size Requirements for the Chase Car Study.¹⁹

Cycle Development Considerations

- Speed Correction Factor Improvement Study, Estimating Sample Size Requirements for the Chase Car Study.¹⁹
- Validity of Chase Car Data Used in Developing Emissions Cycles.¹⁷
- Estimating Regional Air Quality Vehicle Emission Inventories: Constructing Robust Driving Cycles.²⁴
- Statistical Methods for Estimating Speed Correction Factors with Confidence Intervals for Mobile Source Emissions Models.²⁹

Dynamometer Testing

None until completion of testing

Table 2. Summary of Sacramento, San Francisco, San Joaquin Valley, and South Coast (Los Angeles) travel behavior data collection effort.

Metropolitan Area	Data Collection Period	Number of Routes Driven	Lock-on Target-Vehicle Hours of Travel Data Collected	Urban vs. Rural VMT distribution (based on 2000 HPMS data)		Lock-on Rates (% time chase vehicle was locked onto a target vehicle)
				Urban	Rural	
Sacramento 7% of statewide VMT, based on southern Sacramento Valley counties ¹	February, 23, 2000 – June 2, 2000	140	50	78%	22%	47
San Francisco Bay Area 20% of statewide VMT, based on nine-county region ¹	March 16, 2000 – June 2, 2000	150	74	89%	11%	64
Stanislaus County (Modesto area) 10% of statewide VMT, based on San Joaquin Valley counties ¹	March 27, 2000 – June 2, 2000	120	58	62% ²	38% ²	40
South Coast Air Basin 45% of statewide VMT, based on four-county region ¹	Route-based driving August 30-31, 2000 & September 6-8, 2000	100	37	97%	3%	67 (at the point when 83% of data collection effort was complete)
	Segment-based freeway driving November 6-9, 2001 & November 12-16, 2001	I-105 fwy I-110 fwy	46			91

Source: Sierra Research CAMP status reports prepared during 2000, 2001, and 2002.

Notes:

1. California Motor Vehicle Stock, Travel and Fuel Forecast; p. 44. Caltrans, November 1999.
2. San Joaquin Valley Urban vs. Rural VMT Data for Stanislaus County only.