NCHRP

REPORT 462

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Quantifying Air-Quality and Other Benefits and Costs of Transportation Control Measures

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NCHRP REPORT 462

Quantifying Air-Quality and Other Benefits and Costs of Transportation Control Measures

CAMBRIDGE SYSTEMATICS, INC.
Cambridge, MA

SUBJECT AREAS
Planning and Administration • Energy and Environment

Research Sponsored by the American Association of State Highway and Transportation Officials
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration, U.S. Department of Transportation.

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FOREWORD

By Staff
Transportation Research Board

This report presents potential improvements to the analytical framework for assessing the air quality and other benefits and costs of transportation air quality control strategies. Short- and long-range improvements are included that will enhance the metropolitan planning models being used and considered in major metropolitan areas. The report also discusses how a monitoring program can augment quantitative analysis to provide a fuller understanding of the air quality impacts of transportation control measures. A CD-ROM containing more detailed research results is included with the report. Air quality specialists will find the report helpful, particularly when considering improvements to their analysis systems.

The Clean Air Act Amendments of 1990 (CAAA) identify transportation control measures (TCMs) that are expected to provide emission-reduction benefits and other measures intended to modify motor vehicle use. In addition, depending on the area's nonattainment status, the CAAA mandates implementation of some of the TCMs. States and metropolitan planning organizations require specific, quantitative information on the benefits, costs, and expected air-quality improvements of various TCMs in order to select those TCMs that will best meet agency needs.

Under NCHRP Project 8-33, Cambridge Systematics evaluated current analysis techniques for estimating the impacts of TCMs on emissions. The research team then developed and tested a comprehensive framework for analyzing TCMs, including those designed to produce mode shifts, operational traffic changes, and reductions in motor vehicle usage. The testing used data from Sacramento, California, and Portland, Oregon. The framework is also useful for assessing other types of benefits and costs.

Cambridge Systematics also examined how air quality monitoring could augment emissions analysis in determining the effectiveness of TCMs. This effort consisted of a thorough assessment of the issues and a careful analysis of the transportation and measured air quality changes associated with the 1996 Olympic Games in Atlanta, Georgia.

The report summarizes the research conducted and presents a list of recommended improvements to those modeling methods that are in common use. Priorities are assigned to each improvement based on its importance to TCM analysis and the ease of implementation. The report describes alternative methods of monitoring air quality and assesses their appropriateness for evaluation of TCMs. Findings from throughout the research effort are included to promote better understanding of the issues.

In the interest of brevity, considerable technical material has been consigned to a companion CD-ROM included with the report. The CD-ROM contains the following documents:

- Appendix A: Portland Pilot Testing
- Appendix B: Analytical Framework for the Evaluation of Air Quality Transportation Control Strategies

- Appendix C: Summary of Ambient Air Measurement Evaluation Studies
- Interim Report: Feasibility of Using Advanced Air Quality Monitoring Systems
- Interim Report: Use of Remote Sensing and Personal Exposure Monitors
- Interim Report: Relationships Between Monitored Air-Quality and Traffic During the Atlanta Olympics
- Interim Report: Freeway Speed Correction Factors
- Interim Report: Immediate Improvements to Current Analysis Techniques
- *NCHRP Research Results Digest 217: Relationships Between Implemented Transportation Control Measures and Measured Pollutant Levels*
- *NCHRP Research Results Digest 223: Development of an Improved Framework for the Analysis of Air Quality and Other Benefits and Costs of Transportation Control Measures*
- *NCHRP Research Results Digest 230: Review of Travel Assumptions Employed in Emission Factor Models*

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John H. Suhrbier, a Principal of Cambridge Systematics, served as the principal investigator. Other Cambridge Systematics participants included Yoram Shiftan, Chris Porter, Steve Decker, Maren Outwater, Rich Kuzmyak, Vassili Alexiadis, Nageswar Jonnalagadda, Elizabeth Harper, Xudong Jia, Douglas Sallman, and Esther Kim.

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QUANTIFYING AIR-QUALITY AND OTHER BENEFITS AND COSTS OF TRANSPORTATION CONTROL MEASURES

SUMMARY

OBJECTIVE

State departments of transportation (DOTs) and Metropolitan Planning Organizations (MPOs) are facing numerous analytical challenges in their attempts to evaluate transportation control measures (TCMs) and to conduct other associated transportation air quality analyses. While numerous advances have been made in recent years and examples of good analyses can be cited, there are many other examples where the underlying analysis is deficient in one or more respects. Combined with improvements in the understanding of transportation, emissions, and air quality interrelationships, far-reaching improvements are needed in the analytical methodologies used to conduct TCM and related transportation air quality analyses.

The objective of NCHRP Project 8-33 was to develop and test potential improvements to the analytical framework for assessing the air quality and other benefits and costs of TCMs within the context of an area's total transportation system. Initial emphasis was given to identifying the important causal variables, examining their inherent uncertainty, and determining the degree to which they are correctly represented in current analysis procedures. Attention then was given to identifying improvements that could be immediately implemented by state DOTs and MPOs, as well as to evaluating more fundamental enhancements that would require a longer time frame to fully develop and implement. Because the interest is in identifying TCMs whose emissions reduction credit is sufficiently large enough to result in an improvement in regional ambient air quality levels, primary attention was given to analytical approaches that could be applied on an areawide basis rather than to site-specific methods. Most of the findings, though, also are applicable to analyses of specific sites.

The basic outline of the recommended analytical framework is broad in scope. Although numerous improvements to current analysis methodologies can be immediately implemented and although these will result in more accurate estimates of transportation, emissions, and other impacts, critical shortcomings will still remain. The long-term need is essentially for an entirely new set of analytical capabilities rather than just improvements to current modeling approaches. These new analytical capabilities, however, generally can be implemented incrementally.

Transportation, emission, and air quality analyses need to be more effectively linked than they are at present in order to include the variables required to produce spatially and temporally distributed emission inventories of the desired accuracy. This requires a combination of new analytical approaches with expanded and better monitoring data. Improved analytical capabilities, to be effective, will require new and different types of data. Although doing a better job of developing the data needed to support current analytical methods is important, it is not by itself sufficient to overcome the deficiencies in today's analyses. Equally important, this new generation of transportation air quality analytical capabilities should take advantage of emerging computational environments, rather than continue to rely on outdated batch-mode computer programming techniques.

WORK PROGRAM

Beginning with a comprehensive assessment of recently completed and ongoing research combined with a workshop of potential users, the research

- Identified improvements in transportation, emissions, and air quality analysis capabilities which can be immediately implemented by state DOTs and MPOs; and
- Defined more fundamental changes to today's current analysis approaches, which can be implemented incrementally over a number of years.

Testing conducted in cooperation with the Sacramento Area Council of Governments (SACOG) focused on a set of transportation and emissions modeling improvements that easily can be immediately implemented to current network-based, four-step travel demand forecasting analytical methodologies. These include the incorporation of peak spreading, the incorporation of traffic speed-flow relationships defined by facility type and geographic area, recoding of the highway network, the use of facility-specific speed correction factors to estimate emissions, and the separation of trip-end from running emissions. These enhancements were then used to evaluate the impacts of a proposed regional system of high-occupancy-vehicle (HOV) lanes and ramp metering.

Testing conducted in Portland, Oregon, in contrast, concentrated on methodologies that are longer range for most transportation planning organizations in terms of the likely time horizon for their implementation. Major elements tested in Portland included the use of activity- and tour-based travel demand models for estimating emissions, household sample enumeration-based forecasting, and the use of stated preference survey data to evaluate the effects of potential changes in the choice of residential living patterns. Where an important element of the Sacramento testing was a comparison of enhanced to existing modeling approaches, the primary purpose of the Portland testing was to demonstrate the feasibility of recommended new analytical approaches and to gain experience with their application.

To accurately estimate the effects of transportation improvements on air quality, it is necessary to have a sound understanding of the relationships between transportation activity and emissions from mobile sources. The following emissions-related research activities were undertaken:

- Important transportation-related assumptions embedded within the Environmental Protection Agency's (EPA) MOBILE and the California Air Resources Board's (CARB) EMFAC emission factors models were documented so that transportation agencies can be aware of potentially important data premises that implicitly are being incorporated in their analyses.

- Driving behavior and resulting vehicular emissions on a sample of metered and unmetered freeway ramps were investigated in order to determine the feasibility and desirability of incorporating ramp- and functional class-specific speed correction factors in emission factor models.
- Newly developed modal emissions models, the transportation variables required by these models, and the manner in which these models can be introduced into transportation practice were examined.

An important objective of the NCHRP 8-33 research was to assess the relationship between implemented TCMs and changes in monitored air quality levels. Toward this end, three specific activities were undertaken:

- The feasibility and desirability of using air quality monitoring techniques to evaluate the effectiveness of implemented transportation control measures was investigated.
- Monitored traffic and air quality data during the 1996 Atlanta Summer Olympics were analyzed to determine the relationship between the program of transportation system management measures implemented during the Olympics and changes in ambient pollutant levels during this same period.
- The feasibility of using remote sensing techniques and personal monitors to either supplement or serve as an alternative to the use of traditional air quality monitoring and measurement approaches for assessing the improvements in ambient air quality associated with the implementation of TCMs was examined.

FINDINGS

An Emerging View of TCMs

An examination of current transportation planning practice indicates that the traditional view of TCMs no longer is appropriate. Significant attention is being given to the manner in which both existing and new transportation infrastructure is being managed. As a result, entirely new forms of transportation management strategies are being intensively considered throughout the country and rapidly being deployed. These include intelligent transportation systems (ITS), a diverse array of market-based pricing mechanisms, land use and growth management policies, alternate work or trip schedules, and the use of information technologies as a substitute for travel. Typically implemented as part of a larger overall transportation operations program, each of these emerging strategies and technologies has important implications for the volume and schedule of travel and, thus, on the efficiency of vehicle and system operations.

In developing and applying improved TCM analytical capabilities, it is useful to have an idea of both the potential magnitude and the associated uncertainty of the expected travel and associated impacts. Such information is helpful in determining the resources that should be devoted to a more in-depth analysis. While empirical before-and-after findings on TCM effectiveness are limited, they do provide some indication of the potential magnitude of the impacts of these strategies. In the case of measures affecting travel demand, while selected site-specific programs have resulted in substantial reductions in single-occupancy-vehicle (SOV) work trips, these cases are not the norm. Experience in the 1990s with areawide employer-based programs has shown that an overall reduction in SOV work-trip mode share on the order of 5 percent may be realistic. This translates into vehicle miles of travel (VMT) impacts for all trips at a regional level of considerably less than 1 percent. These results are consistent with evaluations conducted during the early 1980s, which also showed regionwide VMT impacts of under 1 percent. Potential impacts of measures affecting traffic operations have been found to be somewhat greater. Traffic signal coordination and control strategies have resulted in fuel use reductions in the range of 8 to 15 percent within the specific corridors or subareas where the improvements were implemented. Nevertheless, even with widespread adoption of these improvements, the regional impacts are diluted to perhaps 1 to 4 percent.

Sacramento Field Testing

- The implementation of ramp meters and add-a-lane HOV facilities generally increased VMT slightly, but this impact cannot be considered significant (typically less than 1.0 percent). The inclusion of ramp meters without HOV lanes can either increase or decrease VMT, depending on relative congestion on the system. Again, this is not considered to be a significant impact.
- Significant and larger changes in VMT resulted from the inclusion of the three model enhancements that were tested. The use of increased speeds and steeper volume delay curves increased VMT by 10.5 percent and 1.3 percent, respectively, and the inclusion of peak spreading decreased VMT by 6.9 percent.
- Changes in average trip length indicate a redistribution of traffic when implementing TCMs, such as ramp meters and HOV facilities. The most interesting conclusion is that inner and outer screenlines often have opposite impacts in terms of VMT. For instance, adding ramps and HOV facilities tends to increase VMT for inner screenlines and decrease VMT for outer screenlines. The ramp meters and HOV facilities tend to redistribute the traffic in the corridors where they are implemented and decrease travel from areas further away.
- Locating ramp meters specific to demand is critical to the evaluation of VMT because ramp meters can cause delay, rather than alleviate it, if the demand is too low.
- The incorporation of facility-specific speed correction factors in the California EMFAC7F model leads to an increase in emissions of total organic compounds (TOG) and carbon monoxide (CO). This reflects the fact that freeway correction factors for both pollutants show higher emission levels at most speeds relative to the current correction factors. Similarly, there are significant increases in TOG and CO levels estimated for metered versus non-metered ramps. The comparison of NO_x levels is more complex because the freeway correction factor shows lower NO_x levels at most speeds relative to the existing correction factors, whereas the NO_x correction factors for metered ramps are above those of non-metered ramps. The estimated overall reduction in NO_x reflects the net of these two offsetting effects, with the decrease due to operation on all freeways offsetting the increase in NO_x on metered ramps.

Examining the results of the Sacramento testing within the context of the larger objectives defined for the NCHRP 8-33 project indicates that the package of travel and emissions modeling enhancements implemented to SACOG’s existing procedures resulted in more accurate estimates of travel volumes, speeds, and emissions, and were accomplished within the resources typically available within an MPO. These modeling enhancements, though, had a larger impact on the performance measures of interest than did the proposed system of HOV lanes and ramp metering. Further, the modeling enhancements tended to result in increased estimates of travel and emissions. Implementation of a peak spreading capability was considered to be the most important of the enhancements implemented. However, the implementation of facility- and area-specific speed-volume relationships, in conjunction with enhanced network coding, is essential if the advances being incorporated in the MOBILE and EMFAC models are to be used effectively by transportation agencies. The Sacramento TCM analyses did not just rely on executing the mode choice step of the travel forecasting process. Rather, the full model chain was run, including traffic assignment. The changes resulting from these other steps, taken both individually and cumulatively, were important in assessing the overall regional effects of the proposed HOV lane and ramp metering capabilities.

Although the particular set of analysis enhancements were selected primarily because of their potential to improve the accuracy with which the effects of HOV lanes and ramp metering could be estimated, these same enhancements are useful for other types of TCMs as well, especially those affecting the operation of a transportation system and the time of day for both commute and non-commute travel. Importantly, these enhancements serve as a starting point for the implementation of other, longer time horizon improvements to an agency's analysis capabilities.

Portland Field Testing

Work performed in cooperation with Portland Metro, the MPO for the Portland, Oregon, metropolitan area, focused on more fundamental changes that could be made by transportation agencies over a mid- to long-range time horizon that would improve the ability of transportation models to predict variables that are important to accurately estimating emissions and air quality impacts of transportation actions, including the development of data to support these improved methodologies. Three specific modeling enhancements were evaluated:

- The use of activity-based travel demand models;
- The use of household sample enumeration forecasting techniques; and
- The use of stated preference surveys and modeling approaches, applied both independently and in combination with traditional revealed preference techniques.

The following represents an overall assessment of the Portland testing.

1. The Portland work carried out as part of NCHRP Project 8-33 and other ongoing FHWA-sponsored projects indicates that the development and application of activity-based transportation modeling is feasible. This is perhaps the most important finding from this Portland testing. The capabilities of such models will only improve in the future. Even this first generation set of Portland models introduces dramatically improved transportation and air quality analysis capabilities when compared with conventional four-step modeling approaches. The proposed analysis techniques, both individually and in combination, improve the accuracy with which transportation impacts of TCMs, as well as other transportation actions potentially affecting emissions and air quality, are estimated. A wider range of impacts are predicted, and indirect effects are taken into consideration.
2. The identification of synergistic effects of air quality transportation control measures requires use of the kind of integrated transportation modeling system demonstrated in the Portland testing. The highly complex interactive behavioral effects are unlikely to be captured either by monitoring person and household travel or by highly simplified modeling approaches. Residential choice, employment choice, and trip-making behavior simply are too complex to be fully captured in other

than an activity-based transportation modeling system. At the same time, the synergistic effects estimated for the particular mix of policies analyzed in this Portland testing were slightly negative rather than positive as normally hypothesized. Once a shift in individual transportation behavior is induced, additional transportation actions directed toward the same end will have a decreasing marginal effectiveness.

3. The Portland testing indicates that data requirements are increased if the objective is to improve the accuracy of estimated emission and air quality impacts of transportation actions. The use of improved analytical methodologies is not sufficient by itself. The underlying data necessary to support the development and application of these techniques also must be available. While tour-based travel demand models can be estimated using standard travel survey data, the extension to full activity-based modeling is likely to require the collection of a broader range of data items over a longer period.
4. Household sample enumeration, stated preference techniques, and tour-based activity modeling are well within the resource capabilities of transportation agencies to implement and apply. The use of full activity-based transportation modeling, though, has considerably higher resource implications in terms of the level of professional skills, data, implementation and application costs, and computer capabilities required. Immediate practical barriers to the widespread application of activity-based transportation modeling are the processing time and memory demands placed by this style of modeling on even high-end personal computers. While this type of equipment eventually will be available in most transportation agencies, it does not yet come close to representing the norm.
5. Household sample enumeration is used as the technique for applying the Portland system of travel activity models. This same microsimulation technique, though, can be used in conjunction with other types of disaggregate travel demand models. A major benefit is that it preserves the full distribution of household demographic and socioeconomic variables, thereby facilitating the analysis of distributional effects of a candidate transportation action.
6. The Portland testing demonstrates the applicability and practicality of stated preference survey and modeling techniques, used both individually and in combination with traditional revealed preference techniques. Stated preference data can be especially helpful in evaluating candidate policies where a base of existing implementation experience is lacking. Stated preference techniques also can be useful where the potential impacts may be small and difficult to differentiate from those of changes in other variables. The valid application of stated preference survey and modeling techniques, though, is not easy. The determination of external validity of stated preference data is a particular problem.
7. Applying an aggressive set of land use and growth management policies is effective at influencing residential location choice decisions, although the coefficients of the stated preference residential choice model also indicate that people value housing characteristics associated with traditional suburban living patterns. The forecast changes in residential housing location, though, do not translate into corresponding reductions in household travel.

The analytical methodologies applied in the Portland testing add considerable value, demonstrating behavioral insights that simply are not possible with conventional four-step transportation modeling approaches. While Portland Metro must be considered an example of a state-of-the-art MPO, activity-based modeling and forecasting will likely begin to be used throughout the United States over the coming years. This introduction, however, will occur in an evolutionary or transitional manner over a period of years, rather than being undertaken as one large and immediate change.

Improvements to Emissions Models

The MOBILE model developed by the EPA and the EMFAC model developed by the CARB are the emissions factor models currently used to produce fleetwide emission estimates. Numerous concerns about the performance of these regulatory models, however, have been raised in recent years. The accuracy of the estimated magnitude and distribution of emissions is very much dependent on the accuracy of the underlying vehicular emission rates. Improving the accuracy of the transportation models will accomplish little if emission modeling data and procedures are not simultaneously improved.

The existing assumptions built into the MOBILE and EMFAC models regarding the relationship between average speed and vehicle emissions do not enable the models to be used reliably to evaluate operational improvements that smooth traffic flow (e.g., ramp metering, signal coordination, and many ITS strategies). To the extent that such operational improvements reduce acceleration events and the queuing of vehicles, they may produce emissions benefits that are inconsistent with estimates based on the use of the speed correction factors presently built into MOBILE and EMFAC.

Immediate Priorities

The following are important emissions-related data or modeling topics where improvements would be particularly beneficial:

- Driving profile,
- Fraction of cold and hot starts,
- Time and location of starts,
- Travel by vehicle class and time-of-day,
- Travel by facility type and time-of-day,
- Trip ends with hot soaks, and
- Freight (truck versus rail) and passenger (non-motorized, access to transit) modal alternatives.

Both the EPA and CARB recognize the existing problems associated with using MOBILE and EMFAC to estimate the emission impacts of transportation system improvements. Both agencies, therefore, are in the process of collecting data and developing new analysis techniques to improve the performance of these existing models.

In addition to improving the accuracy and the level of detail of the transportation data that are input to emissions, it is important that transportation personnel also appreciate the implications of the travel assumptions that are embedded internally within an emissions model. These assumptions have an important influence on the accuracy of resulting emissions estimates. Further, it may be possible in many cases to adapt these built-in assumptions so that they reflect locality-specific rather than national conditions.

One category of travel activity where there could be a direct link to travel models and surveys is the estimate of vehicle class-specific trips per day. The average number of trips that a vehicle makes per day is used in emission models to estimate the number of times that a vehicle is started per day. This information is used to estimate both the start component of exhaust emissions and evaporative emissions that are a function of the time between vehicle starts.

New emissions models, however, are changing the approach used to estimate starts. These now contain estimates of the number of starts, not trips, based on the results of data collected by instrumented vehicles placed in customer service. The data show that the light-duty vehicles contained in this sample experience roughly 50 percent more starts than indicated by the trip data collected in transportation surveys. The source of the discrepancy is thought to be short trips (e.g., moving vehicles in driveways, shopping centers, trip chaining, etc.). While the capture of these trips will improve the accuracy of emission estimates, it complicates the use of travel information in developing emission inventories because a relationship is now needed to adjust the estimate of the number of trips produced by transportation planning models to account for the short trips that are not now captured in the transportation modeling process.

Finally, a review of the methods used to develop heavy-duty truck and bus forecasts shows that the data for these vehicles frequently are derived from forecasts of light-duty vehicles. Given the significance of heavy-duty vehicles to NO_x emission estimates (typically over 50 percent of the mobile source NO_x inventory), this practice is a problem. Heavy-duty vehicle travel is not directly proportional to light-duty vehicle travel; it is not distributed in proportion to light-duty travel by hour of the day (in contrast to light-duty vehicles, the peak period of operation for heavy-duty vehicles is typically during the middle of the day); and heavy-duty vehicles do not travel at the same speeds as light-duty vehicles, except under the most congested conditions. New methods need to be developed to address these issues.

Facility-Specific Speed Correction Factors

In response to the increasing scrutiny on the emissions impacts of transportation improvements, both EPA and CARB are incorporating facility-specific speed correction factors in their respective emissions models. Given the increasing focus on ramp operation as both a capacity improvement and emissions reduction strategy, research was undertaken to assess the differences in vehicle operation and related emissions impacts on metered and non-metered ramps. The results are based on limited vehicle operation data collected on a sample of ramps located in Sacramento, California.

Two separate driving cycles were developed to represent vehicle travel on metered and non-metered freeway ramps. The cycles were constructed to match the observed speed-acceleration frequency distribution observed on each type of ramp. The average speed on metered ramps is 15.1 mph while the average speed on non-metered ramps is 40.8 mph. There also is a substantial difference in the observed maximum acceleration rates, with metered ramps showing roughly double the rate observed on non-metered ramps. The results show that freeway on-ramp emissions, on a grams-per-vehicle-mile basis, are much higher than emissions from general driving represented by the Federal Test Procedure (FTP), and emissions from metered ramps are roughly double the emissions from non-metered ramps.

Modal Emission Models

Independent of improvements to current emission factor models, efforts are underway to develop an entirely different class of emission model referred to as “modal emission” models. It is likely that modal emissions modeling will gradually be introduced into transportation practice over the coming years.

A major objective of these modal models is to overcome the assumptions embedded in the current MOBILE and EMFAC regulatory models regarding the relationship between average speed and emissions. In a modal emissions model, analysis is performed to identify the modes of vehicle operation responsible for significant differences in emissions performance. Tests are then performed to measure emissions from these modes of operation for a sample of vehicles that represents the in-use fleet.

The result of this research on modal emissions models is that a far wider spectrum of modeling approaches is becoming available to estimate motor vehicle fleet emissions than previously has been available. Models range from simple regional approaches employing very few highly aggregated emission rate and activity variables to the highly disaggregate, employing a large number of disaggregate emission rate and activity variables.

Effects of Transportation Actions on Ambient Air Quality

TCMs and other forms of mobile source air quality control strategies typically are evaluated in terms of their expected magnitude of emissions reductions, with the location and timing of these emission changes occasionally also examined. The ultimate objective of implementing air quality transportation control strategies, though, is to improve ambient air quality. Ultimately, a judgment must be made if a candidate TCM or combination of TCMs is likely to display an aggregation of benefits that significantly exceed the costs of implementation. Generally speaking, TCMs are expected to have relatively modest impacts (typically under 1 percent) when integrated over larger geographic areas or over longer periods of time. Impacts may be larger on smaller scales and for selected time periods, ranging from 1 to 5 percent and, on occasion, higher. The error in accuracy of both modeling and monitoring exceed these magnitudes significantly. Modeling results may display an imprecision of 25 to 40 percent, and biases of zero to 25 percent or more. Monitoring determinations often have imprecision in the range of 2 to 20 percent; inaccuracies vary and are difficult to generalize. Thus, the challenge is measuring an estimated air quality improvement that is greatly exceeded by the imprecision and/or inaccuracy of the estimate. The decision whether or not to proceed with a recommended TCM unfortunately must be made in light of uncertainty that may completely mask the anticipated outcome.

Four activities were undertaken to determine the potential of using ambient air quality monitoring data, perhaps in conjunction with air quality analysis techniques, to determine the air quality impacts of one or more TCMs. Pollutants of primary concern to transportation agencies include ozone, fine particles (primary and secondary), carbon monoxide, oxides of nitrogen, volatile organic compounds (VOCs), and sulfur dioxide.

Existing Data on the Ambient Air Quality Effects of Mobile Source Controls

Various researchers have employed statistical techniques to analyze ambient measurement data to determine the effects of oxygenated fuel, reformulated gasoline, and vehicle inspection/maintenance programs on ambient air pollution levels. A review of these studies indicates mixed results, despite carefully thought out experimental and analytical approaches. From a purely statistical perspective, most of these efforts were inconclusive.

An examination of these existing studies indicates that statistical approaches are likely to be most successful in discerning effects on ambient air quality levels where control measures result in relatively large reductions in emissions (e.g., greater than 10 percent). Control measures that have a spatially diffuse effect on emissions, such as many forms of TCMs, are much more difficult to discern through the statistical analysis of monitored air quality data.

Similarly, these studies indicate that detecting the effects of emission reductions on monitored levels of a secondary pollutant, such as ozone, is considerably more difficult than detecting changes in primary pollutants, such as CO. As pointed out in a number of the analyses, this does not necessarily mean that these measures are not resulting in improved air quality, only that this determination is difficult to demonstrate with the desired levels of statistical confidence.

One reason for this difficulty in detecting an emission-related effect through statistical analysis of monitored air quality data is the significant variation in pollutant concentrations that occurs naturally because of the stochastic character of the atmosphere and changes in meteorological variables. In situations where a control measure has only a modest influence on emissions, the resulting change in pollutant level is only one component of the overall variability in ambient concentrations. Even though there may be evidence that emissions are reduced, it may not be possible to show the associated change in ambient air quality to the desired level of statistical confidence.

A second reason for problems in correlating emissions and air concentration data is the influence of outside or uncontrolled events. Such events can have a significant effect on the ambient concentrations, yet this may not be accounted for by the statistical modeling techniques.

Changes in Air Quality and Transportation Associated with the 1996 Atlanta Summer Olympics

In an attempt to determine if changes in ambient air quality would result from large-scale regional changes in a transportation system, transportation and air quality data collected in conjunction with the 1996 Olympic Games held in Atlanta, Georgia, between July 19 and August 4, 1996, were analyzed. Major changes were made during the Olympic Games to the highway, transit, and other transportation systems serving the Atlanta region. Together with the Games themselves, these resulted in major changes in virtually all aspects of travel demand, including the time of travel, modal shares, traffic volumes, transit ridership, and travel speeds.

Data from the Olympics indicate that the transportation strategies implemented during the Olympics were largely successful in reducing traffic, particularly during the morning and evening rush hours when unusually low levels of congestion were experienced. Shifted work hours, in particular, are consistent with an observed shift in peak-period traffic to other times of the day. Traffic at some locations decreased by up to 30 percent during the maximum a.m. hour and up to 25 percent during the maximum p.m. hour. Traffic impacts were most notable in the central Atlanta area, with substantially reduced congestion.

Traffic outside of the peak periods showed little change or a slight increase from normal, and it appears that total daily traffic volumes decreased by 5 percent or less. This is remarkable when contrasted with the potential levels of travel given the number of visitors in Atlanta during this period. The traffic and transit data suggest that a large percentage of visitors used transit to access events, particularly in the Olympic Ring area. Overall, given the number of visitors to the Atlanta region in addition to the base level of travel by residents, the smooth operation of the transportation system was a considerable accomplishment.

During the period of the Olympics, raw ozone data from six Atlanta area monitoring sites indicated a 10 to 20 percent decrease in ozone. Statistical analysis based on meteorological variables also indicated an overall 18 percent decrease in maximum ozone levels among the six sites. A comparison of ozone levels at other sites in the southeastern United States, however, indicated a regionwide decrease during the same period. In particular, ozone decreased by roughly 25 percent in Birmingham, 150 miles west of Atlanta, while winds during this period were consistently from the west. This suggests that regional meteorological factors largely if not fully explain the decrease in ozone levels in Atlanta during the Olympics.

Feasibility of Using Advanced Air Quality Monitoring Systems to Evaluate TCMs

Four aspects are critical in designing a monitoring-based air quality evaluation program to measure the effects of TCMs:

- Spatial scale,
- Experimental control,
- Conditions for maximizing the ratio of signal to noise, and
- Duration of the monitoring program.

The primary conclusion resulting from the feasibility assessment of using a research or advanced air quality monitoring system to evaluate TCMs is that such systems are technically feasible in appropriate situations. The expense associated with implementing such specialized monitoring programs, though, may be relatively high, and, in many cases, may be comparable to or even greater than the costs of the TCMs themselves. Consequently, a careful assessment of the costs and benefits of such monitoring programs is necessary. The result is that such evaluation programs are likely to be undertaken only in highly specialized situations as part of a national-level research effort.

- **Air quality monitoring is technically feasible for primary pollutants, such as CO, VOCs, and NO_x.** Measurements of upwind concentrations can be subtracted from the downwind values as a means for characterizing the contribution of a roadway to ambient downwind concentrations. Experiments should be conducted both prior to and subsequent to implementing the TCMs.
- **TCM effects on secondary pollutants require a combination of monitoring and modeling approaches.** For a secondary pollutant, such as ozone, the focus should be to characterize the effect of the TCM on the pertinent precursor species (e.g., VOCs and NO_x) through near-roadway measurements. A combination of modeling and data analysis should be used to investigate the effects on downwind ozone formation.
- **It is feasible to observe TCM effects only if they exceed a certain threshold value.** For primary pollutants, this is on the order of 2 percent. Direct observation of TCM effects on secondary pollutants is considerably more difficult. A threshold at which a precursor emissions change would produce an observable change in downwind ambient ozone concentrations may be on the order of at least 10 percent.
- **Monitoring over a large geographic area to determine the effects of areawide TCM programs is inherently more difficult than monitoring on a location- or facility-specific basis.** The implication is that use of an air quality monitoring program to evaluate the synergistic impacts on ozone levels of a coordinated urban area program of TCMs is technically extremely difficult.
- **Specialized TCM air quality monitoring programs are costly.** Preliminary estimates indicate that the cost of two 3-month monitoring programs (one before and the other after implementation) to examine the effects of TCMs on peak-hour CO levels downwind of a congested intersection (assuming an impact on emissions of about 10 percent) would be on the order of $500,000. If the effect on emissions is

> smaller (e.g., requiring two 1-year programs), then the cost would be on the order of $1,000,000. Two 3-month programs to study effects on ozone formation would cost on the order of $1,300,000. Because of these high costs, it probably is not practical for local transportation or air quality agencies to undertake such specialized monitoring programs. This kind of research-grade monitoring, though, could be undertaken as part of a national research program.

Potential of Remote Sensing and Personal Exposure Monitors

Two alternatives to the use of traditional air quality monitoring techniques were assessed to determine their potential applicability for evaluating the air quality impacts of TCMs:

- Remote sensing techniques and
- Personal exposure monitors.

The more promising of these alternatives consists of remote sensing techniques, typically installed along the roadside. This technology is similar to that currently being used or considered for supplementing vehicle inspection/maintenance programs. While these systems measure vehicle emissions and not ambient air quality, they offer two important advantages over conventional monitoring approaches. First, it is possible to collect a large number of samples (i.e., measurements of emissions from individual vehicles) over a relatively short period of time. Second, measurements of tailpipe emissions are less influenced by variations in meteorological conditions and the need to accurately determine both upwind and downwind concentrations. The estimated cost to hire a contractor to deploy such a system for 1 month is approximately $50,000. Costs would be reduced if a system were already available and could be deployed and operated by agency personnel. Since measurements must be conducted both before and after implementing the TCM, the total cost would be approximately $100,000 or less.

Evaluation

It is common to rank TCMs based on a cost-effectiveness ratio of cost per ton of pollutant emissions reduced. While such a technique may be useful as a screening device, an approach to TCM evaluation is recommended based on net present value. This approach is economically sound and can be consistently applied. The objective is to calculate the “net cost” of a TCM, based on comparing the net present value of a time stream of costs and benefits, where the value of such non-air quality effects as fuel and operating cost savings are subtracted from the cost of implementation. If the time stream of benefits exceeds total costs, then the “net cost” becomes negative.

Cost-effectiveness, particularly in the area of transportation, frequently is incorrectly and inconsistently applied. Because the kinds of measures are so diverse and because much of the required information is unknown, it is very difficult to be both comprehensive and correct. In almost all cases, it is useful to examine the sensitivity of the analysis results to alternative input assumptions.

Although cost-effectiveness analysis is useful, it is recommended that this technique not be relied upon as the primary means for evaluating transportation air quality control strategies. It is difficult to interpret negative costs per ton; there are different levels of objectives being achieved; and the analysis does not address the geographic and economic distribution of impacts, making it difficult to be responsive to the full range of political issues that are important to successful implementation. This technique, though, can serve as a valuable supplement to a broader evaluation where impacts are displayed by type and magnitude and their incidence upon particular groups.

WHERE ARE WE HEADING?

Mobile sources will continue to be an important element of national, state, regional, and local air quality analyses, with increased emphasis given to fine particles, $PM_{2.5}$, and the role of NO_x in ozone formation. An examination of changes in vehicular emissions has been satisfactory in the past as the primary output of interest. In the future, increasing interest is likely to be placed on the relationship between changes in the transportation system and actual changes in ambient air quality levels.

Further, increased focus will be given to emissions associated with heavy-duty vehicles and the movement of freight; for example, the concern about diesel particulate emissions as a toxic air contaminant. Transportation air quality analyses in the past have concentrated primarily on the movement of persons, and even person movement occurring within the peak weekday travel period. Increasingly, air quality is being incorporated into analyses of intermodal freight improvements.

An important question is whether existing and projected transportation, emissions, and air quality modeling capabilities are sufficient to satisfy the desired requirements for a quantitative analysis. The findings of this research indicate that, although selected MPOs have demonstrated important leadership with respect to the implementation of improved transportation air quality analysis capabilities, the overall state of the practice lags significantly behind the state of the art. Numerous data and modeling enhancements have been successfully developed and applied by one or more MPOs or state DOTs that could be immediately adopted by other transportation agencies. It may be unrealistic to expect all agencies to employ today's best practices. It is within existing budget and personnel resources, though, for transportation agencies in the short term to move toward better practices.

Despite this short-term potential, critical shortcomings, unfortunately, still will remain. Eliminating deficiencies in the variables used to link transportation emissions and air quality analyses is especially important if accurate estimates of spatially and temporally distributed emissions impacts are to be produced. The long-term need is for essentially a new set of analytical capabilities rather than just incremental improvements to current modeling approaches. These longer run improvements require a combination of improved analytical methodologies and better data.

Equally important, this new generation of transportation air quality analytical capabilities should take advantage of emerging computational environments. These include geographic information systems (GIS), distributed databases, and distributed computing technologies. TCM air quality analyses, to date, have resulted from a piecing together of independently developed travel demand and emissions modeling tools. The result has been inflexible approaches to complex problems. Further, these existing tools have been in use for many years now, largely unchanged by emerging computer technologies.

Looking even a few years into the future, significantly improved transportation, emissions, and air quality analysis capabilities will be gradually introduced that will alleviate many of today's most serious analytical deficiencies with respect to the evaluation of transportation air quality control strategies. There is no question of whether this will happen; capabilities such as activity-based travel demand models, modal emission models, and EPA's Models-3 air quality system already are being deployed. The only question is the time that will be required for this new generation of analytical capabilities to be broadly introduced into practice. While it is unlikely to happen within an immediate 2- or 3-year future, the state of the art of transportation air quality analyses

10 years from now almost certainly will be far superior to today's best practices and dramatically different from today's current practices.

We have become accustomed to using a relatively fixed and stable set of transportation air quality analysis capabilities. The techniques in use today do not differ that much from those employed 10 and even 20 years ago. It is likely that changes in transportation air quality analysis practices will occur much more rapidly in the future than they have in the past.

Increased attention in transportation air quality analyses will be given to examining the temporal and spatial distribution of transportation-related emissions and air pollution. This almost certainly will be accomplished through the use of GIS-based databases and analyses having the ability to integrate demographic, travel, emissions, and air quality information. Two factors are motivating this trend. The first is that air pollutant levels, particularly for secondary pollutants, are very much dependent on the temporal and spatial distribution of emissions. Thus, the pattern of mobile, stationary, and area sources of emissions needs to be understood to improve the accuracy of estimated changes in air quality resulting from the implementation of one or more air quality control strategies. Second, increased attention is being given to issues of environmental justice, including the distribution of both adverse air pollutant levels and implementation characteristics by income level and population. Conducting this type of analysis requires an examination of the spatial distribution of emissions and air quality. Thus, analysis approaches that rely either primarily or exclusively on areawide impact estimates no longer will be satisfactory. Instead, the emphasis will be on examining impacts by different combinations of individual household characteristics.

Air quality analyses increasingly are being conducted for multistate regions, reflecting the multistate regional formation and transport of secondary pollutants. Examples include the Lake Michigan Ozone Study, the Southern Oxidant Study, and the 37-state Ozone Transport Analysis Group. This increase in the size of the analysis area represents a significant shift from the traditional focus on individual sites, urban areas, or even state-level analyses. This also means that a consistent set of transportation data must be developed on a multistate regional basis. Network-based transportation air quality analyses will continue to be useful, but these results must be integrated with transportation and emissions data from areas where network analysis capabilities may not be present. This also means that transportation data need to be developed for multiday episode periods, including weekend, as well as weekday, travel conditions. In concert with these larger geographic-scale air quality analyses, there is a growing interest on the part of non-transportation professionals in the analysis of TCMs and other transportation-related air quality control strategies. This includes environmental organizations and industry associations interested in reducing emissions from within the transportation sector. These groups want to use methods that mirror their own analytical framework, rather than relying on traditional transportation analysis approaches that they neither understand nor accept.

Given the personnel, budget, and program demands facing transportation and air quality agencies, there is an understandable desire for simplified analysis techniques. Indeed, many such techniques have been developed in recent years in an attempt to meet these demands. While some of these "sketch planning" techniques do a better job than others in satisfying the analysis criteria defined by this research, the examination of emerging transportation, emissions, and air quality analytical approaches indicates that future methodologies will be more complex and data intensive than existing techniques. This is a natural byproduct of introducing more of the important causal variables into the analysis. Examples include traffic operations effects, the use of a more detailed vehicle fleet distribution, and the desire to differentiate trip-based from running emissions. The result is that the data and technical needs required to support transportation air quality analyses will become more, rather than less, daunting. Simplifying assumptions still can be developed, but these new relationships need to evolve from a set of underlying analytical techniques and data that are more solidly grounded than those in use today.

NEXT STEPS

This report describes a recommended analytical framework and associated methodologies for use in evaluating the air quality and other benefits and costs of transportation control measures. It is anticipated that over the next 10 to 15 years, a fundamentally new set of transportation, emissions, and air quality analysis capabilities will be developed and implemented. The report, therefore, is useful to state DOTs and MPOs in developing a multiyear work program for developing and implementing improved transportation air quality analysis capabilities. Specific methodologies are described for analyzing the transportation, emissions, air quality, and other benefits and costs of transportation management strategies. Implementation activities in the short run should be directed at facilitating the implementation of longer-term and more fundamental improvements.

It is recommended that attention be given to parallel deployment and research programs. Simultaneous testing and deployment of incremental changes will both accelerate the overall implementation process and improve the effectiveness of a long-term research program. For example, considerable research already has been completed with respect to both activity-based travel demand modeling and modal emissions modeling. While continued research can be justified on each of these topics, there is a need to move existing research into implementation and application. These implementation activities should include selected testing and demonstration activities, technical assistance, training, and the convening of user forums to promote the exchange of information among users. Care should be taken to include development of less sophisticated analytical capabilities applicable to smaller and medium-sized areas having less access to technical resources, as well as more robust approaches for use by larger transportation and air quality agencies. The desire in each case, though, is to move toward state-of-the-art analytical practices.

CHAPTER 1

INTRODUCTION

The Clean Air Act Amendments of 1990 (CAAA) and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) created numerous analytical challenges for state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) in their attempts to evaluate transportation control measures (TCMs) and to conduct other associated transportation air quality analyses. While examples of both good and improved analyses can be cited, there are many other examples where the underlying analysis is deficient in one or more respects. Combined with improvements in the understanding of transportation, emissions, and air quality interrelationships, fundamental improvements are needed in the analytical framework used to conduct TCM and related transportation air quality analyses.

The basic characteristics of the current set of analytical methodologies used by transportation agencies to support the requirements of the Clean Air Act, ISTEA, and the Transportation Equity Act for the 21st Century (TEA-21), were developed nearly 30 years ago. Furthermore, the transportation, emissions, and air quality components were developed largely independent of each other and for basically different purposes than the ones for which they are now being used. Transportation models developed to support the design and construction of new or expanded infrastructure are serving as the underlying basis for spatially and temporally distributed emission inventories. While the resulting sequence of linked models "works" in that numbers are produced, serious reservations exist concerning the accuracy of their results, the robustness of the underlying data, and even whether the correct set of variables are captured in these current model systems. In addition, the scientific knowledge of this nation's air pollution problems, especially with respect to particulate matter and ozone, continues to improve. As a result, renewed attention is being given to the potential impacts that various forms of air quality transportation control strategies may have on ambient pollution levels.

The objective of NCHRP Project 8-33 was to develop and test potential improvements to the analytical framework for assessing the air quality and other benefits and costs of TCMs within the context of an area's total transportation system. Emphasis was given to identifying the important causal variables, examining their inherent uncertainty, and determining the degree to which they are correctly represented in current analysis procedures. Attention also was given to identifying improvements that could be immediately implemented by state DOTs and MPOs, as well as to evaluating enhancements that would require a longer time frame to fully develop and implement. Because the interest is in identifying TCMs whose emissions reduction credit is large enough to result in an improvement in regional ambient air quality levels, primary attention was given to analytical approaches that could be applied on an areawide basis rather than to site-specific methods. Most of the findings, though, also are applicable to analyses of specific sites.

Work was undertaken in three basic phases as illustrated in Figure 1.1. The objective of the first phase was to outline an overall analytical framework, including the identification of improvements that could be implemented immediately by state DOTs and MPOs. Work activities included the convening of a workshop of potential users and a comprehensive assessment of potential relevant research that either recently had been completed or currently was underway. The Phase I research activities also included an assessment of past efforts to relate implemented TCMs and other forms of mobile source control measures to actual changes in ambient pollutant levels.

The basic outline of the analytical framework recommended at the conclusion of Phase I was intentionally broad in scope. While numerous improvements to current analysis methodologies could be immediately implemented and while these would result in more accurate estimates of transportation, emissions, and other impacts, critical shortcomings would still remain. The long-term need is for a fundamentally new set of analytical capabilities rather than just improvements to current modeling approaches (Figure 1.2). These new capabilities, however, generally can be implemented incrementally. Transportation, emission, and air quality analyses need to be more effectively linked than they are at present in order to include the variables required to produce spatially and temporally distributed emission inventories of the desired accuracy. This requires a combination of new analytical approaches with expanded and better monitoring data. Improved analytical capabilities, to be effective, will require new and different types of data. While doing a better job of developing the data needed to support current analytical methods is important, it is not by itself sufficient to overcome the deficiencies in today's analyses. Equally important, this new generation of transportation air quality analytical capabilities should take

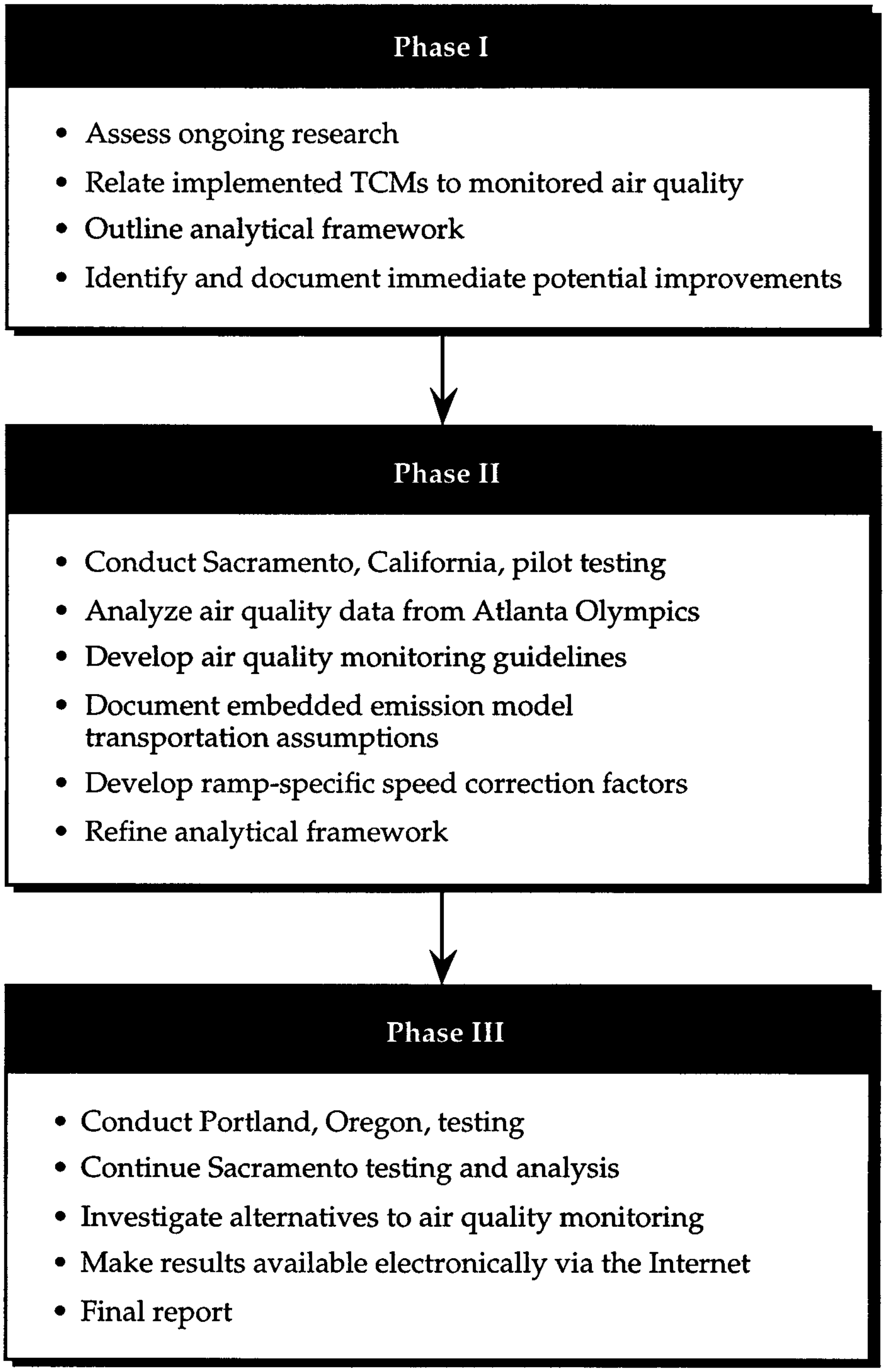

Figure 1.1. Overview of work program.

advantage of emerging computational environments, rather than continue to rely on outdated batch-mode computer programming techniques.

A high-priority objective of NCHRP Project 8-33 was to determine the appropriate role for monitoring in evaluating the implementation effectiveness of TCMs, in contrast to relying primarily or even exclusively on a set of analysis tools such as the four-step urban travel demand models, the MOBILE emissions factor model, and the Urban Airshed Model (UAM). The data to be monitored can include ambient air quality as well as transportation variables and vehicular emissions. The conclusion from the research performed is that an improved transportation air quality analysis framework should incorporate a reasonable balance of both data monitoring and quantitative modeling. Neither a monitoring nor a modeling approach by itself is sufficient to discern the air quality and

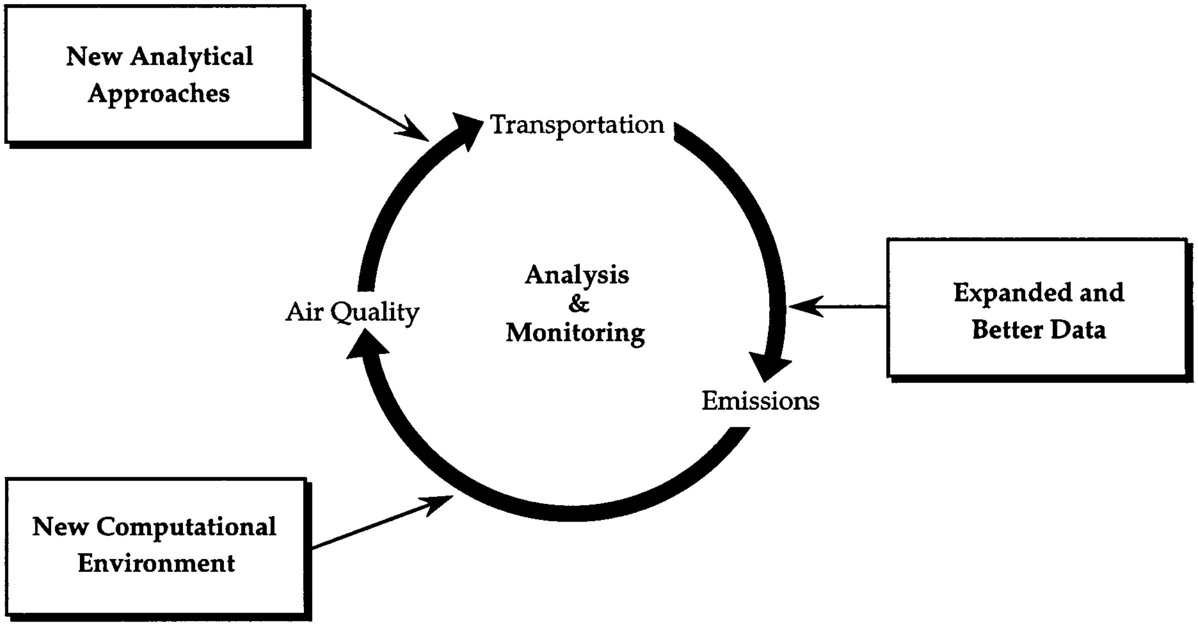

Figure 1.2. Components of an improved TCM analytical framework.

other impacts of transportation measures. A carefully constructed combination of data monitoring and quantitative analysis is required to fully understand the air quality-related impacts of transportation measures.

Given the inherently comprehensive scope of the transportation air quality analysis process, the recommended improved analytical framework was developed with different time frames in mind (Figure 1.3). Specifically, it is recommended that a longer-term "target" in terms of what is ideally needed to model transportation emissions and air quality impacts be used by transportation and air quality agencies as a guide in their decisions as to what is "realistic" in terms of specific techniques that can be implemented and applied within nearer-term time horizons. Over a long-range time horizon, fundamentally new analysis approaches will be possible using information and analytical technologies that are

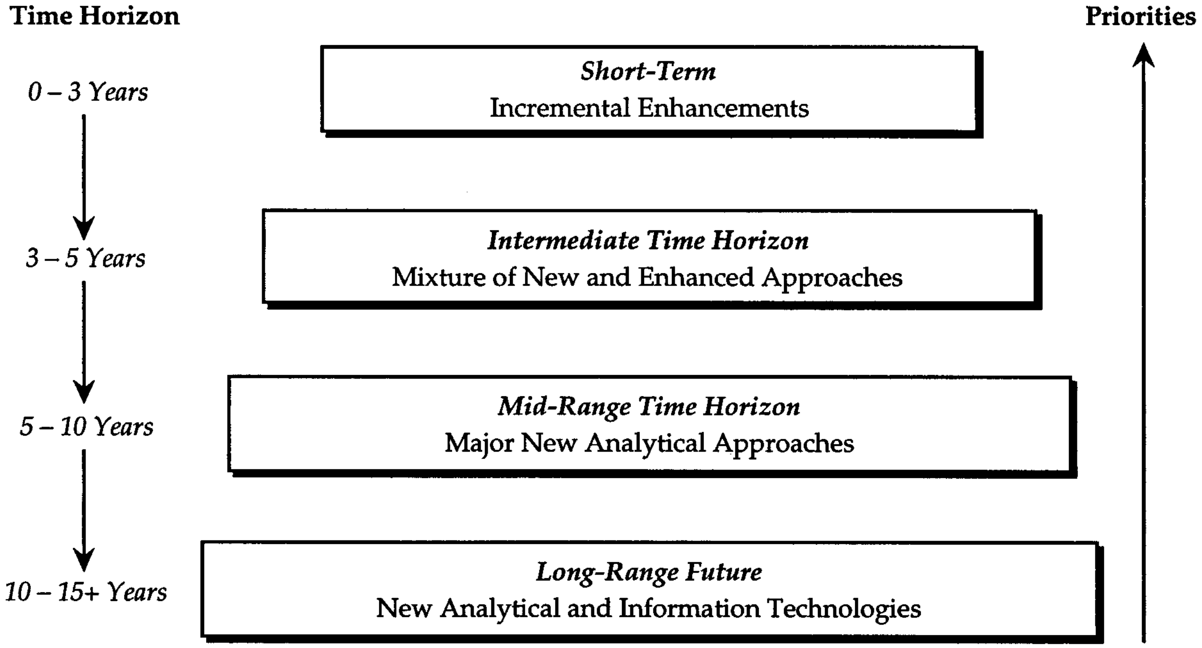

Figure 1.3. Time horizons for implementation of a new TCM analysis framework.

likely to become available in coming years. This long-range or "ideal" future then can be used to prioritize the changes that are desirable for more intermediate time horizons. The long-range analytical framework can be characterized as one that fully utilizes emerging electronic information technologies. It also may not necessarily be driven by specific analytical requirements contained in the 1990 CAAA and its associated implementing regulations and guidelines. While the full complement of these desired analytical capabilities may not be practically available for more than 10 or even 15 years, they establish a direction in which transportation air quality practice should head.

While attention should be given to the long-range research and development activities necessary to develop an essentially new analytical framework, numerous enhancements can be made immediately to existing analysis approaches that will improve the accuracy of estimated emission and air quality impacts. These improvements in accuracy can be achieved by focusing on those variables, such as vehicle speed and acceleration, that serve to link transportation, emissions, and air quality, and by examining the spatial and temporal distribution of emissions from transportation sources, rather than just the overall magnitude.

To further the development and testing of the recommended analytical framework, the research undertaken as a part of NCHRP Project 8-33 involved each of the major components illustrated in Figure 1.2 and the different time horizons defined in Figure 1.3. The work completed during the second and third phases of the research was structured around the following eight principal activities, some of which are oriented to immediately improving transportation air quality analysis techniques while others have a longer-range time horizon in terms of their potential payoff (see Figure 1.4):

- Incorporate a program of analytic improvements in the transportation and air quality modeling system used by the Sacramento Area Council of Governments (SACOG), and assess the benefits of these improvements in evaluating a proposed areawide system of high-occupancy-vehicle (HOV) lanes and freeway ramp metering;
- Adapt and utilize the new activity-based travel demand models developed for the Portland, Oregon, metropolitan area for use in analyzing air quality transportation control strategies, including an examination of the travel and emissions implications of potential growth management policies;

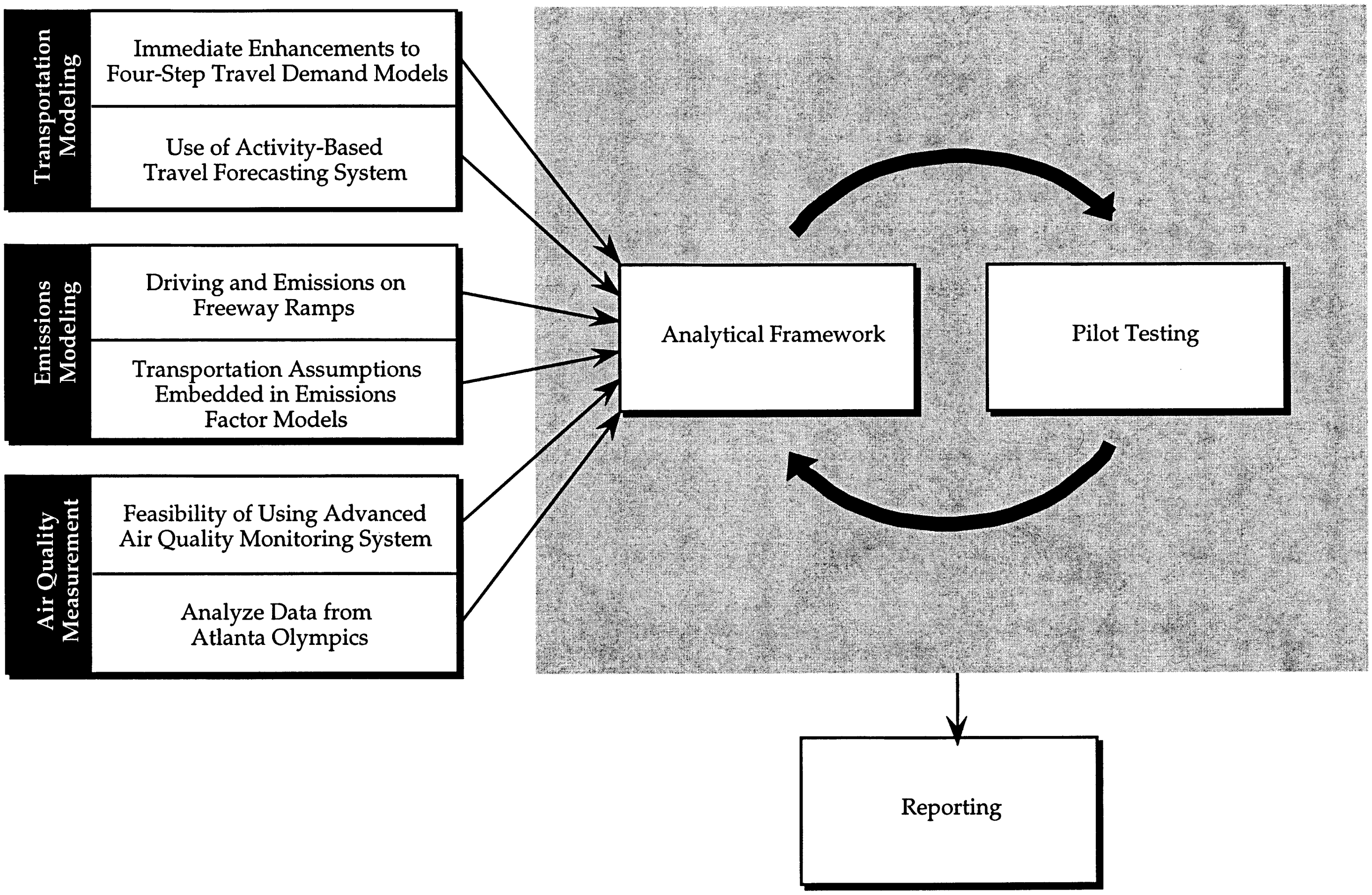

Figure 1.4. Interrelationship of Phase II and III work program activities.

- Investigate driving behavior and resulting vehicular emissions on a sample of metered and unmetered ramps in order to determine the feasibility and desirability of incorporating ramp- and functional class-specific speed correction factors in emission factor models as a step toward better capturing modal emissions;
- Document important transportation-related assumptions embedded within the Environmental Protection Agency's (EPA) MOBILE and the California Air Resources Board's (CARB) EMFAC emission factors models so that transportation agencies can be aware of potentially important data premises that implicitly are being incorporated in their analyses;
- Investigate the feasibility and desirability of using air quality monitoring techniques to evaluate the effectiveness of implemented transportation control measures;
- Examine the feasibility of using remote sensing techniques and personal monitors to either supplement or serve as an alternative to the use of traditional air quality monitoring and measurement approaches for assessing the improvements in ambient air quality associated with the implementation of TCMs;
- Analyze monitored traffic and air quality data during the 1996 Atlanta Summer Olympics to determine the relationship between the program of transportation system management measures implemented during the Olympics and changes in ambient pollutant levels during this same period; and
- Expand and refine the overall recommended analytical framework based on the results of the testing carried out using data from Sacramento, California, and Portland, Oregon.

The testing conducted in cooperation with the SACOG focused on a set of transportation and emissions modeling improvements that easily can be immediately implemented by MPOs and state DOTs to their current network-based, four-step travel demand forecasting analytical methodologies. In contrast, the testing conducted in cooperation with Portland Metro concentrated on methodologies that are longer range for most transportation planning organizations in terms of the likely time horizon for their implementation. Major elements tested in Portland included the use of activity- and tour-based travel demand models for estimating emissions, household sample enumeration-based forecasting, and the use of stated preference survey data to evaluate the effects of potential changes in the choice of residential living patterns. Where an important element of the Sacramento testing was a comparison of enhanced to existing modeling approaches, the primary purpose of the Portland testing was to demonstrate recommended new analytical approaches and to gain experience with their application.