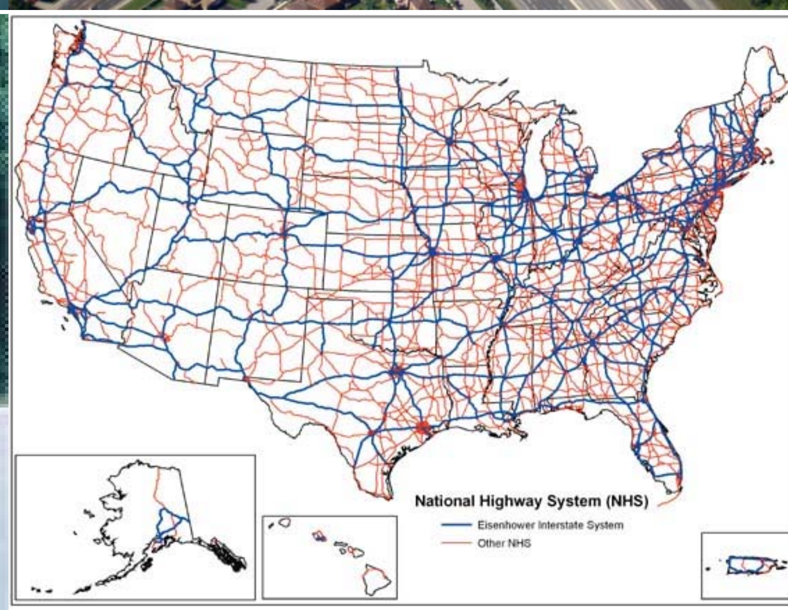
Strategic Plan for Particulate Matter Research: 2005 to 2010



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Sonoma Technology, Inc.

1360 Redwood Way, Suite C
Petaluma, CA 94954-1104
707 / 665-9900
Fax 707 / 665-9800
www.sonomatech.com

STRATEGIC PLAN FOR PARTICULATE MATTER RESEARCH: 2005-2010

FINAL REPORT
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By:
Michael C. McCarthy, Ph.D.
Douglas S. Eisinger, Ph.D.
Hilary R. Hafner
Todd M. Tamura
Lyle R. Chinkin
Paul T. Roberts, Ph.D.
Sonoma Technology, Inc.
1360 Redwood Way, Suite C
Petaluma, CA 94954-1169

Nigel Clark, Ph.D.
West Virginia University
Dept. of Mechanical and Aerospace Engineering
123/125 Engineering Sciences Bldg.
P.O. Box 6106
Morgantown, WV 26506-6106

Peter H. McMurry, Ph.D.
University of Minnesota
Particle Technology Lab
111 Church Street SE
Minneapolis, MN 55455

Arthur Winer, Ph.D.
University of California, Los Angeles
School of Public Health, Environmental Science & Engineering
10833 Le Conte, Room 46081
Los Angeles, CA 90024

Prepared for:
Kevin Black
U.S. Federal Highway Administration
Office of Natural Environment
400 7th Street SW HEPN-10, Room 3240
Washington, D.C. 20590

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As part of the process for identifying and prioritizing the research issues for the transportation community, STI, together with Dr. Nigel Clark of West Virginia University, Dr. Peter McMurry of the University of Minnesota, and Dr. Arthur Winer of the University of California at Los Angeles, hosted a particulate matter (PM) research needs workshop on April 7, 2005, for FHWA. The workshop's success was due in great measure to the energetic and talented support provided by a number of the participants who took on leadership roles during the day. On behalf of the entire study team and FHWA, STI extends its appreciation to the following individuals for their workshop assistance; the workshop findings were an important contributor to the development of the strategic plan for PM research:

Workshop Presenters

Kevin Black, FHWA
Nigel Clark, West Virginia University
Chris Klaus, North Central Texas Council of Governments
Peter McMurry, University of Minnesota
Mike Savonis, FHWA

Breakout Session Facilitators

Stephen Cadle, General Motors
Lisa Graham, Environment Canada
Chris Klaus, North Central Texas Council of Governments

Breakout Session Note Takers

Chad Bailey, U.S. Environmental Protection Agency
Tim Belian, Coordinating Research Council
Hilary Hafner, STI
David Lax, American Petroleum Institute
Paul Roberts, STI
John Watson, Desert Research Institute

In addition, STI especially thanks Dr. Arthur Winer, who generously accepted the challenge to moderate the presentation of breakout session findings and to extemporaneously synthesize the workshop's main themes.

Finally, STI thanks all workshop participants for their individual contributions. Participants came to the workshop with important ideas, questions, and insights that allowed the study team and FHWA to better understand priority research needs related to transportation and PM (Appendix A includes a complete listing of the workshop participants).

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ES.1 OVERVIEW

This Strategic Plan for Particulate Matter Research (Strategic Plan) identifies priority particulate matter (PM) research issues for the transportation community for the years 2005 through 2010. It updates and expands on a previous Federal Highway Administration (FHWA) strategic plan for PM research covering the 2000 through 2004 time period (Carr et al., 2002a). This Strategic Plan identifies areas of research that have the greatest potential to yield insights directly applicable to state Departments of Transportation (DOTs) and regional Metropolitan Planning Organizations (MPOs) charged with developing and implementing transportation plans, programs, and projects. The timeframe for this Strategic Plan extends to 2010 to correspond with $PM_{2.5}$ attainment planning and the timeframe used by the National Research Council (NRC) for its long-range PM research portfolio (National Research Council, 1998).

The FHWA's 1998 National Strategic Plan established the Administration's mission "to continually improve the quality of our Nation's highway system and its intermodal connections" (Federal Highway Administration, 1998). It identified five strategic goals for achieving this mission, one of which was to protect and enhance the natural environment and communities affected by highway transportation. Air quality research, including investigation of PM, was one of the eight program goals established in FHWA's 1998 National Strategic Plan. The document established two criteria for conducting PM-related research: first, to bring a transportation focus to the study of PM issues, and second, to develop applied research products that respond to the needs of transportation and air quality planning practitioners.

Multiple organizations sponsor and coordinate PM research. This Strategic Plan was developed to define areas of research that will ultimately assist state DOTs and MPOs, regardless of whether this research is funded by FHWA or other organizations. While FHWA is most interested in applied research addressing mobile source PM pollution, some of the research priorities identified in this Strategic Plan address fundamental questions about sources, characterization, and monitoring of PM that must be understood to assess the impact of mobile sources. Therefore, some of the research priorities identified in this Strategic Plan may be funded either wholly or partially by organizations or agencies other than FHWA. In addition, the research priorities identified in this Strategic Plan reflect, as of 2005, the consensus view of experts from various geographic regions and institutional affiliations. These priorities will undoubtedly change as new scientific information becomes available. Thus, readers should review the report findings presented in this Strategic Plan as a tool to assist in identifying and prioritizing research, but not as an absolute guide.

ES.2 BACKGROUND

PM is the term used to describe a complex mix of solid and liquid particles in the air that can adversely impact the environment and human health. PM is known to contribute to regional haze, global climate change, and acid rain and has also been linked to health outcomes such as asthma, strokes, and decreased life expectancy. On-road mobile sources (i.e., motor vehicles) can directly emit PM in exhaust, or contribute to PM in the air from tire wear, brake wear, and road dust. In addition, mobile sources emit gases that can react or condense in the air to form secondary PM.

National Ambient Air Quality Standards (NAAQS) for PM regulate concentrations of two sizes of PM; particles with aerodynamic diameter smaller than 2.5 microns ($PM_{2.5}$ or the "fine" fraction) and those with aerodynamic diameter smaller than 10 microns (PM_{10}; note that $PM_{2.5}$ is also a subset of PM_{10}). Most PM emitted from motor vehicle exhaust is within the $PM_{2.5}$ and PM_{10} size categories. Failure to attain the NAAQS for PM, or to meet progress milestones while working towards attainment, can result in loss of federal highway funding for local, regional, or state governments.

Federal "transportation conformity" regulations require that state and local governments and their transportation agencies participate in and contribute to the air quality planning process. Areas that do not attain the NAAQS (nonattainment areas)—and areas that attain, but were previously designated as nonattainment (maintenance areas)—are required to develop State Implementation Plans (SIPs). The SIPs must include regional conformity emissions budgets, meaning caps on allowable emissions, for PM and PM precursors from on-road transportation sources. The SIPs must also demonstrate how emission reductions from mobile sources and other sources will result in attainment and maintenance of the NAAQS. The deadline for states to submit $PM_{2.5}$ SIPs to the U.S. Environmental Protection Agency (EPA)is 2008.

In the nonattainment and maintenance areas, MPOs and DOTs are also required by the conformity process to demonstrate that transportation plans and programs conform to SIPs and that projects do not create or exacerbate violations of the NAAQS. Conformity is demonstrated by using models to show regional emissions are within allowable budgets and to demonstrate emissions from individual projects do not cause or contribute to NAAQS-related air quality problems (e.g., hotspots near roadways). Project-level air quality analyses can also be required under the National Environmental Policy Act (NEPA).

ES.3 RESEARCH RECOMMENDATIONS

Approach

This 2005 to 2010 PM Strategic Plan for PM research is the third of three steps FHWA has taken as part of its current process to identify and prioritize PM research issues for the transportation community. The first step involved completion of an assessment of recent and ongoing PM research and research plans (Tamura et al., 2005). The second step involved an FHWA-sponsored one-day workshop where atmospheric scientists, air quality experts, industry experts, members of the academic community, and environmental and transportation planners from state and regional DOTs, MPOs, and air quality agencies discussed and prioritized the key research topics facing the transportation community (McCarthy et al., 2005). The third step involved synthesizing the results of the assessment document and the workshop into a Strategic Plan for PM Research (this report).

Findings

Prioritized research topics are organized into one of five research categories: monitoring, characterization, emissions measurements, emissions and hot-spot (or localized) modeling, and control strategies. Each of the five research categories corresponds to research areas defined by the FHWA during the development of its first PM research plan (Carr et al., 2002a).

This Strategic Plan identifies high-, medium-, and low-priority research issues. During the one-day workshop, a voting process was used to quantify the level of interest among workshop participants for specific research opportunities. The votes, categorized by all workshop participants and by the subset of participants representing the MPO-DOT community, clearly identified high priority research needs; these were used as a guide to develop the priority ranking presented here. **Table ES-1** provides a description and illustration of each of the high priority research issues. **Table ES-2** lists the high, medium, and low research priorities resulting from the literature assessment and workshop processes. The Table ES-2 color scheme was chosen to reflect that used in the 2000 to 2004 Strategic Plan.

The main contribution from FHWA's work efforts has been to achieve broad consensus across a wide range of stakeholder groups that four transportation-related PM research issues are of highest priority for the 2005 to 2010 time period. The highest priority research issues are:

- monitor near roadways,
- evaluate PM hot-spot concentration models,
- develop and evaluate PM emissions models, and
- evaluate control strategy programs.

FHWA intends to work with its partner agencies and with other stakeholders to provide funding or other forms of support for research efforts. Completion of research efforts will advance understanding about the relationship between on-road mobile sources and PM problems, provide improved analysis tools for SIP and conformity analyses, and facilitate identification and implementation of effective PM control strategies.

Table ES-1. High-priority research issues.

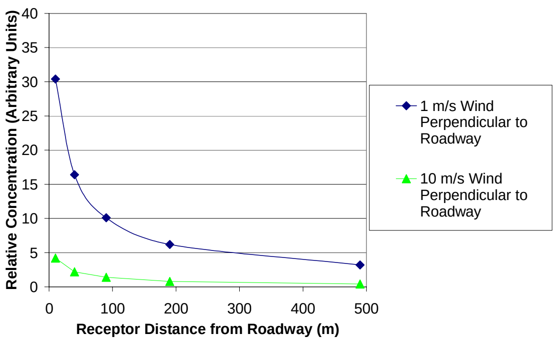
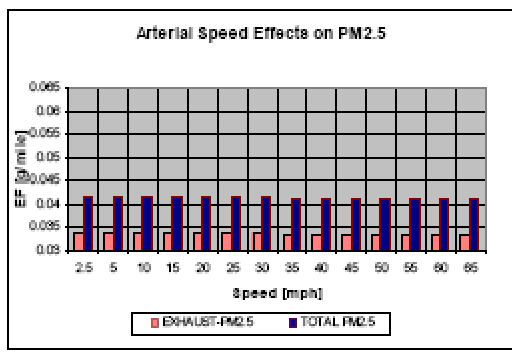
Illustration	Issue
	**H1. Near roadway monitoring is needed to evaluate hot-spot modeling tools, determine concentration gradients of PM and precursors near roadways, and to support health effects research.** Current United States monitoring networks do not monitor near roadways. *The illustration is an example monitoring unit deployed near roadways by the UCLA-based Southern California Particle Center.*
	**H2. "Hot-spot," or localized, PM models need to be evaluated.** Although conformity requirements for PM have not yet been finalized, the EPA has announced that hot-spot models may be applicable to "hot-spot" PM evaluations. The ability of new and existing models to predict PM emissions and concentrations at the micro-scale needs to be evaluated for a wide variety of roadway types and travel conditions. *The illustration is CAL3QHC model output showing downwind pollutant concentration decay as the distance from the roadway increases.*
	**H3. Research is needed to correct known deficiencies in MOBILE6.2 and resuspended road dust emissions models.** Important examples related to PM include a lack of speed correction factors, the inability to model effects of traffic signal changes, and the inability to model varying travel conditions that affect acceleration changes. Model results need to be evaluated using emissions test data and real-world measurements. *The illustration, from an FHWA study, shows that certain MOBILE6.2-based estimates of vehicle PM exhaust emissions are insensitive to changes in travel speed.*
	**H4. The efficacy and costs of control strategy programs need to be evaluated.** In particular, it is important to test if real-world emission reductions are consistent with predicted reductions. In addition, cost-benefit and off-model analysis techniques should be improved to more accurately credit PM control opportunities. *The illustration shows high occupancy vehicle lane implementation in Denver, Colorado. Photo courtesy of the Denver Regional Transportation District (RTD).*

Table ES-2. Prioritized research issues categorized within research topic areas. Each issue is numbered in the order of its relative priority ranking (e.g., M1 is the highest medium priority; M10 is the lowest medium priority). Rankings are based on participant feedback derived from an FHWA-sponsored PM research workshop held April 7, 2005.

Basic Research				Applied Research	
	Monitoring	Characterization[c]	Emissions Measurements	Emissions and Hot-Spot Models	Control Strategies
High	H1. Monitor near roadways			H2. Evaluate hot-spot models. H3. Develop and evaluate PM emissions models.	H4. Evaluate control strategy programs.
Medium	M7. Improve PM measurements.[a] M8. Increase the spatial extent and temporal resolution of PM measurements.[a]		M1. Collect information on fugitive dust emissions.[b] M5. Evaluate roadway project effects on emissions. M9. Collect exhaust emissions from gross-emitters.[a]	M3. Create short-term MOBILE6.2 fixes. M6. Improve information for MOBILE6.2 users regarding default assumptions.[a] M10. Estimate uncertainty in the emissions/planning/air quality process.[a]	M2. Compile a compendium of control strategy information. M4. Create a data information repository for MPOs/DOTs.
Low		L1. Support model evaluation and improvements. L4. Determine contribution of mobile sources to ambient PM concentrations. L6. Provide adequate data to support air quality model evaluation.	L2. Improve information on ultrafine particles in exhaust. L7. Collect exhaust emissions for non-gross-emitters. L7. Evaluate dilution issues for condensable mass.	L5. Develop models for ultrafine particles. L7. Ensure that hot-spot and air quality models start where emissions models end.	L3. Develop guidance for weighing offsetting air quality and transportation goals (ozone, PM, air toxics, safety, and mobility).

[a] Priority was rated low by MPO and DOT workshop participants, although workshop participants as a whole rated this topic a medium priority.
[b] Priority was rated high by MPO and DOT workshop participants, although workshop participants as a whole rated this topic a medium priority.
[c] The characterization topic area includes references to air quality or receptor models, tools that are typically used by air quality management agencies, rather than by MPOs or DOTs.

1. INTRODUCTION

1.1 OVERVIEW

This Strategic Plan for Particulate Matter Research identifies priority particulate matter (PM) research issues for the transportation community for the years 2005 through 2010. It updates and expands on a previous Federal Highway Administration (FHWA) strategic plan for PM research covering the 2000 through 2004 time period (Carr et al., 2002a). This Strategic Plan is intended to define areas of research that have the greatest potential to yield insights directly applicable to state Departments of Transportation (DOTs) and regional Metropolitan Planning Organizations (MPOs) charged with developing and implementing transportation plans, programs, and projects. A key DOT and MPO concern is the ability to demonstrate that long-range regional transportation plans (RTPs), shorter-term transportation improvement programs (TIPs), and individual transportation projects meet federal transportation conformity and National Environmental Policy Act (NEPA) requirements. Thus, DOTs and MPOs are interested in research that yields new insights into quantifying and mitigating on-road transportation-related emissions of PM_{10} and $PM_{2.5}$, the two size fractions of PM for which National Ambient Air Quality Standards (NAAQS) have been established. The timeframe for this strategic research plan extends to 2010 to correspond with $PM_{2.5}$ air quality plan preparation and implementation, as well as the timeframe identified by the National Research Council (NRC) for its long-range PM research portfolio (National Research Council, 1998).

1.2 WHAT IS PARTICULATE MATTER?

PM is the term used to describe a complex mix of solid and liquid particles in the air, regardless of chemical composition. The principal chemical components of PM mass are sulfate, nitrate, ammonium, elemental carbon (EC), organic carbon (OC), and geologic material (e.g., road dust). Other trace elements can be detected in PM but do not typically compose a significant fraction of the PM mass. A substantial fraction of ambient PM is not directly emitted as PM (primary emissions) but is instead formed in the atmosphere (secondary formation) through the reactions of gaseous precursors. For example, condensation or chemical transformation of volatile organic compounds (VOCs) results in the formation of secondary OC. On-road mobile sources emit all of these precursors and components to differing extents.

PM ranges in size from very small (a few nanometers) to large (100s of micrometers). Most particles by number are smaller than 0.1 µm (ultrafine), whereas most of the particle mass is contributed by particles larger than 0.1 µm. The current National Ambient Air Quality Standards (NAAQS) for PM regulate mass concentrations of two sizes of PM; particles with aerodynamic diameter smaller than 2.5 microns ($PM_{2.5}$ or the “fine” fraction) and those with aerodynamic diameter smaller than 10 microns (PM_{10}). The mass concentrations of $PM_{2.5}$ are always less than or equal to those of PM_{10} because the $PM_{2.5}$ fraction is included in the measurement of PM_{10}. Most PM emitted from motor vehicle exhaust falls within these (the $PM_{2.5}$ and PM_{10}) size ranges. Health effects research suggests the number of particles may also be an important factor in health outcomes, which implicates the smallest particle sizes (ultrafine particles or $PM_{0.1}$). However, there are no current regulations for particle number or for size ranges smaller than $PM_{2.5}$.

1.3 WHY IS PM IMPORTANT?

PM can adversely impact the environment and human health. PM is known to contribute to regional haze, global climate change, air toxics, and can also be important for acid rain (**Figure 1**). PM has also been linked to health outcomes such as asthma, strokes, and decreased life expectancy. For the transportation planning community, failure to attain the NAAQS for PM, or failure to demonstrate conformity to PM state implementation plans (SIPs), can result in loss of federal highway funding for local, regional, or state governments. The transportation community, therefore, has a vested interest in working with federal, state, and regional air quality agencies to assist in timely attainment of the PM NAAQS.

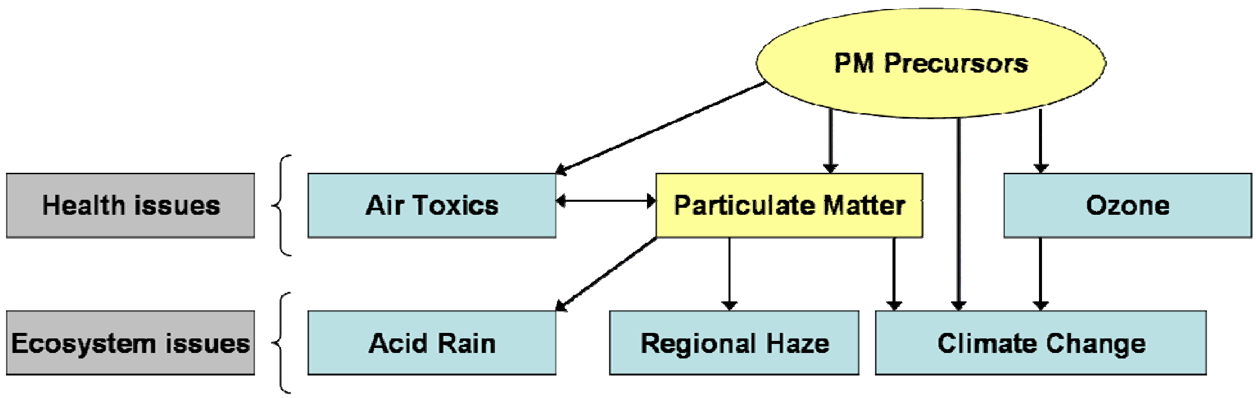


Figure 1. Example relationships among mobile source PM, its precursors, and other air quality issues, modified from Carr et al., 2002a.

1.3.1 Regulatory Framework

Federal regulations require that state and local governments and their transportation agencies participate in the air quality planning process. It is important that local and regional transportation agencies have the tools and knowledge necessary to create realistic emissions estimates, to identify achievable reductions in emissions, and to predict project-level air quality impacts. Near-term research recommendations should focus on issues that can help the transportation community meet the requirements within the current regulatory framework.

Areas that do not attain the NAAQS (nonattainment areas) or that previously have been designated as nonattainment (maintenance areas) are required to develop SIPs that document how the NAAQS will be met or maintained. These SIPs include regional emissions budgets for PM and PM precursors from transportation sources (conformity budgets) and demonstrate how emissions reductions from all sources will result in attainment of the NAAQS. In nonattainment and maintenance areas, MPOs and DOTs are required to demonstrate that transportation plans and programs conform to SIPs and that projects do not create or exacerbate violations of NAAQS (transportation conformity). Conformity is demonstrated by using emissions models to show that regional emissions are within budgets, and by using dispersion models to show that emissions from individual projects do not cause or contribute to NAAQS-related air quality problems (e.g., "hot-spots" or "localized" problems near roadways). In some cases, such as areas that have yet to develop SIPs and emissions budgets, DOTs and MPOs in nonattainment and maintenance areas are required to compare emissions from future "build" and "no-build" scenarios. Project-level air quality analyses can also be required under the National Environmental Policy Act (NEPA).

As part of meeting designated emissions budgets, local MPOs and DOTs are sometimes required to consider emission control strategies at the regional or project level. These control strategies work in concert with federal PM regulations promulgated by the U.S. Environmental Protection Agency (EPA) and regional PM control programs adopted by state and local air quality management agencies. Given the complexity of air quality problems, it is possible that control strategies may decrease the effects of one air quality issue (e.g., ozone, air toxics, haze, global warming, or acid rain) at the expense of increasing the effects of another, or they may conflict with other transportation-related objectives (e.g., mobility and safety). Therefore, a key challenge for the transportation and air quality planning communities is to work across disciplines to develop effective and complementary control strategies.

1.3.2 Potential Regulatory Issues

Pollutant emissions from mobile sources can contribute to high concentrations near roadways, and recent research has identified various potential health hazards linked with proximity to roads with high traffic volumes. Although the chemical or physical mechanisms responsible for these potential health effects are not well-understood, it is possible some combination of ultrafine particles, reentrained road dust (dust resuspended by a vehicle as it drives), diesel particulate matter (DPM), or PM from gasoline vehicles may be responsible. As a result of recent findings linking road proximity and potential health effects, there is growing consideration of restricting certain activities from taking place near high-volume traffic corridors. California, for example, requires that proponents of proposed school sites within 500 feet of busy traffic corridors conduct dispersion modeling and make a determination that exposure does not pose a significant health risk to pupils.

The EPA has identified components of diesel exhaust as a mobile source air toxic (MSAT) (U.S. Environmental Protection Agency, 2001). The state of California has identified DPM as a Toxic Air Contaminant (TAC) and has quantified estimated excess cancer risks associated with DPM exposure (California Air Resources Board and California Office of Environmental Health Hazard Assessment (OEHHA), 1998). A southern California assessment showed that the cancer risk associated with DPM was larger than that of all other air toxics investigated in the study combined (South Coast Air Quality Management District, 2000). DPM can be a component of $PM_{2.5}$ or PM_{10}, but conformity regulations do not address components of PM (or other MSATs). However, requests for localized and/or regional assessments of MSAT impacts have been made, and at least one lawsuit sought to impact whether such assessments will be required for roadways (Shrouds, 2003).

By law, the EPA must periodically review and, as appropriate, adjust the NAAQS. As of mid-2005, the EPA was proceeding under court order to review the PM NAAQS. The EPA is expected to propose a rulemaking action December 2005, and to issue a final rule in September 2006, regarding its PM NAAQS review. If, over time, sufficient scientific evidence accrues suggesting alternative PM NAAQS are appropriate, for example to address concerns related to ultrafine particles, the EPA will change or augment the PM NAAQS.

Existing conformity requirements include qualitative PM hot-spot analyses for primary emissions. As of mid-2005, the EPA was developing updated transportation conformity regulatory requirements for $PM_{2.5}$ and PM_{10} project-level hotspot analyses (U.S. Environmental Protection Agency, 2004c). Depending upon the final rulemaking, transportation agencies may be responsible for completing various qualitative or quantitative project-level $PM_{2.5}$ and PM_{10} assessments.

Finally, upcoming implementation of regulations on low-sulfur fuels (2006) and introduction of cleaner heavy-duty diesel vehicles (2007-2010) are expected to have a major impact on PM emissions from diesel vehicles over a period of several decades. Although substantial PM emission reductions are forecast due to the implementation of the new fuel and tailpipe standards, there have yet to be any real-world data collected to document the emission reduction benefits that will accrue from these programs. Research will be needed to confirm the real-world results of these programs and to compare real-world experience to modeled expectations.

1.4 RESEARCH COORDINATION

Multiple organizations sponsor and coordinate PM research, interagency research planning, and transportation-related PM research. Different agencies and organizations have different responsibilities and focus areas.

The FHWA's 1998 National Strategic Plan established the Administration's mission "to continually improve the quality of our Nation's highway system and its intermodal connections." (Federal Highway Administration, 1998). It identified five strategic goals for achieving this mission, one of which was to protect and enhance the natural environment and communities affected by highway transportation. Air quality research, including investigation of PM, was one of the eight program goals established in the Strategic Plan. The document established two criteria for conducting PM-related research: first, to bring a transportation focus to the study of PM issues, and second, to develop applied research products that respond to the needs of transportation and air quality planning practitioners.

While FHWA is most interested in applied research addressing on-road mobile source PM pollution, some of the research priorities identified in this Strategic Plan address fundamental questions about sources, characterization, and monitoring of PM that must be understood to assess the impact of on-road mobile sources. Therefore, some of the research priorities identified in this Strategic Plan may be funded either wholly or partially by organizations or agencies other than FHWA or the transportation community. Some of these organizations are listed here:

- The FHWA, EPA, and other federal agencies are members of an Air Quality Research Subcommittee (AQRS) of the Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council, under the Office of Science and Technology Policy. The AQRS formed a separate public/private air quality research partnership for North America (including Canada and Mexico) known as NARSTO.
- For research specific to transportation, the Transportation Research Board (TRB), which is a division of the National Research Council (NRC), administers the National Cooperative Highway Research Program (NCHRP). NCHRP is sponsored by individual state DOTs belonging to the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with FHWA.
- The Coordinating Research Council (CRC) is a non-profit organization supported by associations and companies in the automotive and petroleum industries, and by government agencies such as the EPA and the California Air Resources Board (CARB). CRC directs engineering and environmental studies on the interaction between automotive equipment and petroleum products. CRC is also a member of NARSTO.

One of the objectives of this Strategic Plan is to create an information resource that FHWA can use in consultation with its partner agencies and stakeholders to prioritize and support research across the many organizations involved with transportation-related PM. The PM research efforts that FHWA will fund directly will likely be a function of the various research efforts taking place within the broader PM research community. Many of these agencies and organizations have also prepared strategic research plans or reviews of the existing literature; these plans and reviews were among the resources consulted during this study. A short list of documents is provided here for readers interested in more detailed information:

- Research Priorities for Particulate Matter: I-IV by the National Research Council (National Research Council, 2004, 2001, 1999, 1998).
- Particulate Matter Science for Policy Makers (NARSTO, 2004).
- Strategic Plan for Particulate Matter prepared by the PM Research Coordination Working Group of the AQRS of the CENR (Particulate Matter Research Coordination Working Group, 2002).
- The EPA Particulate Matter Research Program: five years of progress (U.S. Environmental Protection Agency, 2004a).
- Air quality criteria for PM (U.S. Environmental Protection Agency, 2004b).
- Transportation and Particulate Matter: Assessment of Recent Literature and Ongoing Research (Tamura et al., 2005).

1.5 DEVELOPING A STRATEGIC RESEARCH PLAN FOR PM

This Strategic Plan for PM is the third of three steps FHWA has taken as part of its current process to identify and prioritize PM research issues for the transportation community.

The first step involved completion of an assessment of recent and ongoing PM research (Tamura et al., 2005). **Table 1** provides a summary of the major research issues identified during the literature assessment step. The second step involved an FHWA-sponsored one-day workshop where atmospheric scientists; air quality experts; industry experts; members of the academic community; and environmental and transportation planners from state and regional DOTs, MPOs, and air quality agencies discussed and prioritized the key research topics facing the transportation community (McCarthy et al., 2005). Appendix A includes a list of the workshop participants. The third step (this report) involved synthesizing the results of the assessment document and the workshop into a cohesive Strategic Plan. **Figure 2** shows this process.

The first step, the literature assessment (Tamura et al., 2005), was the review of past research plans, a survey of current PM and transportation literature, and a description of ongoing PM research initiatives. Research topics were organized in five broad categories, which are discussed in Section 2. These five research focus areas were first identified in the 2000 to 2004 Strategic Research Plan. Briefly, these five focus areas are

- Monitoring – Ambient measurements of PM and precursors at outdoor locations
- Characterization – The use of air quality or receptor models to tie emissions sources to ambient concentrations
- Emissions Measurements – Quantification of vehicle emissions via data collection for in-use vehicles
- Emissions and Hot-spot Models – Models used to calculate emissions or impact of emissions on ambient air concentrations near roadways
- Control Strategies – Measures used to reduce emissions with the intended consequence of improving air quality

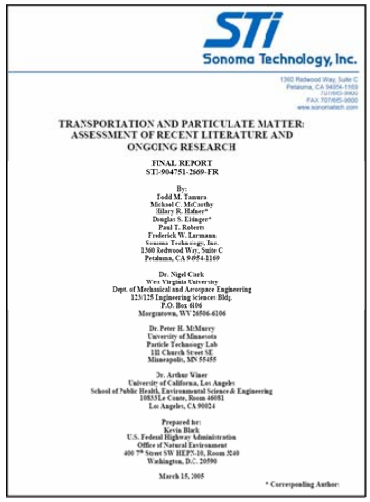
Monitoring, characterization, and emissions measurements topic areas are considered basic research by the transportation community. Emissions models, hot-spot models, and control strategies are considered applied research areas by the transportation community.

Table 1. Research gaps identified during the transportation and particulate matter literature assessment (Tamura et al., 2005). LA-# indicates the number of the issue from the literature assessment document.

Monitoring	Characterization[a]	Emissions Measurements	Emissions and Hot-spot Modeling	Control Strategies
LA-1. Initiate comprehensive near-roadway monitoring	LA-4. Provide adequate data to evaluate and use models	LA-7. Collect exhaust emissions data for PM and precursors from vehicles that are not gross-emitters	LA-13. Improve information for MOBILE6.2 users regarding use of model defaults versus local data	LA-18. Compile a compendium of control strategy information
LA-2. Improve PM measurements	LA-5. Support model evaluation and improvements	LA-8. Collect exhaust emissions data for gross-emitters	LA-14. Develop and evaluate new PM emissions models	LA-19. Evaluate control strategy programs for which information is lacking
LA-3. Increase spatial extent of monitoring networks and temporal resolution of instruments	LA-6. Improve estimates of mobile source contributions to ambient PM	LA-9. Evaluate roadway project effects on exhaust emissions	LA-15. Ensure that hot-spot and air quality models pick up where emissions models leave off	LA-20. Develop guidance for weighing the importance of offsetting factors
		LA-10. Evaluate dilution issues for condensable PM mass	LA-16. Evaluate hot-spot models	
		LA-11. Improve information regarding ultrafine particles in exhaust	LA-17. Develop models for ultrafine particles	
		LA-12. Collect information regarding fugitive dust emissions		

[a] The characterization topic area includes references to air quality or receptor models, tools that are typically used by air quality management agencies, rather than by MPOs or DOTs.

Literature Assessment



Sonoma Technology, Inc.

1360 Redwood Way, Suite C
Petaluma, CA 94954-1169
707/665-9900
FAX 707/665-9800
www.sonomatech.com

TRANSPORTATION AND PARTICULATE MATTER:
ASSESSMENT OF RECENT LITERATURE AND
ONGOING RESEARCH

FINAL REPORT
STI-904751-2669-FR

By:
Todd M. Tamura
Michael C. McCarthy
Hilary R. Hafner*
Douglas S. Eisinger*
Paul T. Roberts
Frederick W. Lurmann
Sonoma Technology, Inc.
1360 Redwood Way, Suite C
Petaluma, CA 94954-1169

Dr. Nigel Clark
West Virginia University
Dept. of Mechanical and Aerospace Engineering
123/125 Engineering Sciences Bldg.
P.O. Box 6106
Morgantown, WV 26506-6106

Dr. Peter H. McMurry
University of Minnesota
Particle Technology Lab
111 Church Street SE
Minneapolis, MN 55455

Dr. Arthur Winer
University of California, Los Angeles
School of Public Health, Environmental Science & Engineering
10833 Le Conte, Room 46081
Los Angeles, CA 90024

Prepared for:
Kevin Black
U.S. Federal Highway Administration
Office of Natural Environment
400 7th Street SW HEPN-10, Room 3240
Washington, D.C. 20590

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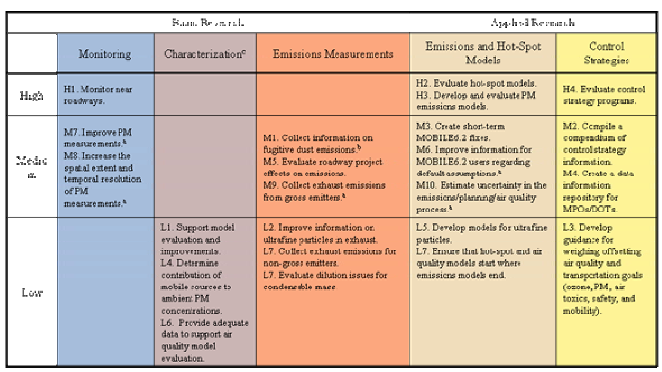
* Corresponding Author

Workshop

Strategic Workplan



	Basic Research			Applied Research	
	Monitoring	Characterization[c]	Emissions Measurements	Emissions and Hot-Spot Models	Control Strategies
High	H1. Monitor near roadways.			H2. Evaluate hot-spot models. H3. Develop and evaluate PM emissions models.	H4. Evaluate control strategy programs.
Medium	M7. Improve PM measurements.[a] M8. Increase the spatial extent and temporal resolution of PM measurements.[a]		M1. Collect information on fugitive dust emissions.[b] M5. Evaluate roadway project effects on emissions. M9. Collect exhaust emissions from gross emitters.[a]	M3. Create short-term MOBILE6.2 fixes. M6. Improve information for MOBILE6.2 users regarding default assumptions.[a] M10. Estimate uncertainty in the emissions/planning/air quality process.[a]	M2. Compile a compendium of control strategy information. M4. Create a data information repository for MPOs/DOTs.
Low		L1. Support model evaluation and improvements. L4. Determine contribution of mobile sources to ambient PM concentrations. L6. Provide adequate data to support air quality model evaluation.	L2. Improve information on ultrafine particles in exhaust. L7. Collect exhaust emissions for non-gross emitters. L7. Evaluate dilution issues for condensable mass.	L5. Develop models for ultrafine particles. L7. Ensure that hot-spot and air quality models start where emissions models end.	L3. Develop guidance for weighing offsetting air quality and transportation goals (ozone, PM, air toxics, safety, and mobility).

Figure 2. Process used to determine transportation community research priorities for this Strategic Plan.

Individual research recommendations were classified under one of these five broad research focus areas. The interrelationship of these research areas is shown in **Figure 3**. Twenty key research recommendations were identified in the literature assessment as shown in Table 1. These research recommendations provided an initial set of topics for discussion at the one-day workshop.

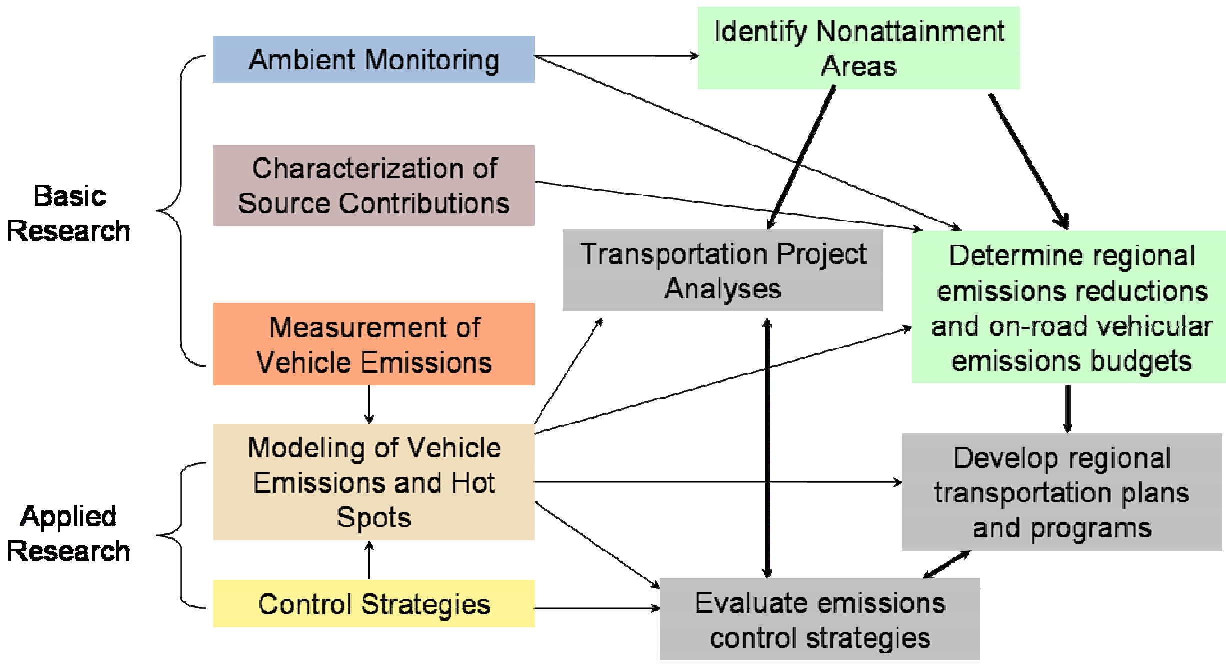


Figure 3. Relationship among broad research topic areas and transportation policy issues. Broad research categories are colored by research topic area (the color scheme is consistent with Table 4 and Figure C-1). Air quality agency tasks are shown in green, and transportation agency tasks are shown in gray. Applied research topics are more likely to be funded by FHWA.

The second step of the process was a one-day multidisciplinary workshop conducted on April 7, 2005 (McCarthy et al., 2005). Approximately 50 members of the academic, government, industry, and consulting communities (10 of whom represented the MPO-DOT community) attended the workshop and discussed the 20 research priorities suggested in the literature assessment (Table 1). In addition, participants were asked to suggest additional research issues that may have been omitted from the literature assessment. Following small-group forums where participants had the opportunity to discuss key research issues, each participant voted to help establish the highest priority research needs. **Table 2** provides a numerical summary of the voting results from the one-day workshop.

During the workshop, some small-group forums identified and prioritized research needs not included in the literature assessment. **Table 3** summarizes the participant voting results for these "newly identified" issues. Two of the new issues discussed were sufficiently similar to combine as one research priority for this document. The two new issues were to disaggregate uncertainty in vehicle activity data and estimate uncertainty in the planning, emissions, and air quality planning process. These were combined under the title "estimate uncertainty in the planning, emissions, and air quality planning process" for the final product.

This Strategic Plan is the third step in the FHWA PM research plan process. The Strategic Plan identifies high-, medium-, and low-priority PM research issues, based on the one-day workshop results. Priorities were assigned using the following criteria:

- Number of workshop votes from all participants.
- Number of workshop votes from MPO-DOT participants.
- Number of votes from individual discussion groups, where groups voted on newly introduced research topics not discussed by all workshop participants.

During the workshop, there was broad agreement between the MPO-DOT participants and the research and government participants on four high-priority and eight low-priority research issues. In other words, for the four top-ranked and the eight lowest-ranked research recommendations, there was widespread agreement among workshop participants independent of their organizational affiliation. This Strategic Plan identifies high- and low-priority research issues based on the broad consensus reached during the workshop. In addition, there were several research issues that were identified as medium-priority by at least one subset of workshop participants, but as either low- or high-priority by other subsets of workshop participants. Topics that were voted as medium-priority by any of the workshop groups (all participants, MPO-DOT participants, or individual groups discussing new topics) are identified in this research plan as medium-priority research issues. **Table 4** summarizes the priorities of the participants of the FHWA workshop for all research issues by category.

Table 2. Participant votes from FHWA workshop, topics discussed by all participants. Priorities are rated high, medium, or low for all participants (right) and for MPO-DOT participants only (left).

Research Issues Discussed by all Workshop Participants (LA-# based on the literature assessment document provided prior to the workshop; see Table 1)			
Issue Description	MPOs and DOTs[a]	Total Votes[a]	Priorities (MPO-DOTs/All)
Monitor near roadways (LA-1)	14	69	H/H
Evaluate hot-spot models (LA-16)	11	45	H/H
Develop and evaluate PM emissions models (LA-14)	11	40	H/H
Evaluate control strategy programs (LA-19)	18	33	H/H
Collect fugitive dust emissions (LA-12)	12	21	H/M
Improve PM measurements (LA-2)	2	21	L/M
Compile a compendium of control strategy information (LA-18)	8	18	M/M
Increase spatial extent and temporal resolution of measurements (LA-3)	0	16	L/M
Collect exhaust emissions data for gross-emitters (LA-8)	0	15	L/M
Improve information for MOBILE6.2 users regarding defaults (LA-13)	3	14	L/M
Support model evaluation and improvements (LA-5)	3	9	L/L
Improve ultrafine exhaust emissions (LA-11)	1	5	L/L
Evaluate roadway project effects on exhaust emissions (LA-9)	4	4	M/L
Develop guidance for weighing offsetting factors (LA-20)	3	4	L/L
Improve estimates of mobile source contributions to PM (LA-6)	1	3	L/L
Develop models for ultrafine particles (LA-17)	1	3	L/L
Provide data to evaluate and use models (LA-4)	1	2	L/L
Research issues LA-7, LA-10, and LA -15 received no votes.			

[a] Individual participants were given a maximum of 10 votes to allocate among the various research issues, with the stipulation that no more than 5 votes be linked to any one research need. There were approximately 50 total workshop participants, 10 of whom were from the MPO-DOT community. Small-group forums included about 12-25 participants, depending on the group. Some individuals chose not to vote or to vote only a portion of their 10 votes.

Table 3. Participant votes from FHWA workshop, new topics identified during small-group forums. Priorities are rated high, medium, or low for all participants (right) and for MPO-DOT participants only (left).

Newly Identified Research Issues Discussed by a Subset of the Participants[a] (research issues identified at the workshop and not included in the literature assessment)			
Issue Description	MPOs and DOTs[b]	Total Votes[b]	Priorities (MPO-DOTs/All)
Short-term MOBILE6.2 fixes	6	15	M/H
Vehicle activity data-disaggregate uncertainty	0	12	L/M
Estimate uncertainty in planning/emissions/air quality process	2	14	L/M
Data/information repository for DOTs and MPOs	3	8	M/M

[a] These issues, identified during individual breakout group discussions, were not discussed by all workshop participants; hence, the vote totals and rankings for these topics reflect only the prioritization by the workshop participants and MPO/DOT attendees who discussed these research issues.

[b] Individual participants were given a maximum of 10 votes to allocate among the various research issues, with the stipulation that no more than 5 votes be linked to any one research need. There were approximately 50 total workshop participants, 10 of whom were from the MPO-DOT community. Small-group forums included about 12-25 participants, depending on the group. Some individuals chose not to vote or to vote only a portion of their 10 votes.

1.6 CAVEATS CONCERNING POTENTIAL FUNDING

Sections 3, 4, and 5 address the high-, medium-, and low-priority research needs. Although, in general, FHWA and other members of the transportation planning community will likely look to fund higher-priority research needs over lower-priority research needs, several caveats are important to mention.

- First, FHWA and other transportation agencies have a stronger interest in applied research than in basic research. As identified in Figure 3, of the five research topics covered in this effort, three topics (monitoring, characterization, and emissions measurements) typically involve basic research, while two topics (emissions and hot-spot modeling and control measures) typically involve applied research. Thus, notwithstanding high-, medium-, and low-priority rankings, there will likely be a general interest among transportation planning agencies to fund emissions and hot-spot modeling and control measure assessment research.
- Second, FHWA and other transportation agencies may have opportunities to leverage their existing research funds by extending research projects supported by other organizations. Thus, for example, an opportunity may emerge to fund, at modest expense, a medium-priority research topic even though other high-priority research needs have yet to be fully addressed. In such a situation, FHWA or other agencies may well take advantage of the opportunity to obtain useful data and information that might otherwise be more expensive to obtain at a later date.

- Third, the high-, medium-, and low-priority characterizations identified in this report reflect input from stakeholders representing various geographic areas throughout the United States and Canada. Priorities in any specific geographic area may vary. FHWA and other agencies may find it important to fund research that assists specific regions with their unique problems.
- Fourth, the high-, medium-, and low-priority needs discussed in this report represent an assessment as of 2005. As new information becomes available, research needs will change.

Thus, readers should view the high-, medium-, and low-priority rankings as a tool to assist in identifying and prioritizing research, but not as an absolute guide. The rankings need to be weighed in the context of emerging scientific knowledge, in consideration of information about ongoing research efforts being carried out by other members of the research community, and with an appreciation for the unique needs of specific geographic regions.

1.7 RESEARCH PRIORITIES ORGANIZED BY COMPLETION TIME

Individual research topics have different timeframes in which results applicable to the transportation community can be expected. Some of the research topics are short- or near-term research goals that can be completed in the next few years. These research issues can aid the transportation community in the near-term, particularly as states develop $PM_{2.5}$ SIPs (due 2008 for submission to the EPA) and complete initial rounds of $PM_{2.5}$ conformity analyses. Other research topics are high-priority items but may not produce useful results for the transportation community for several years (i.e., long-term). Finally, there are some research issues that may have both short- and long-term components. FHWA may consider giving more weight to those research topics where significant progress could be expected in the next few years. A list of the estimated timeframe for various research issues is shown in **Table 5**. Based on FHWA experience implementing the 2000 to 2004 research plan, FHWA may have the ability to fund only a subset of the research issues identified in this report; therefore, the discussion that follows focuses more attention on the higher priority research needs.

Table 4. Prioritized research issues categorized within research topic areas. Each issue is numbered in the order of its relative priority ranking (e.g., M1 is the highest medium priority; M10 is the lowest medium priority). Rankings are based on participant feedback derived from an FHWA-sponsored PM research workshop held April 7, 2005.

	Basic Research			Applied Research	
	Monitoring	Characterization[c]	Emissions Measurements	Emissions and Hot-Spot Models	Control Strategies
High	H1. Monitor near roadways.			H2. Evaluate hot-spot models. H3. Develop and evaluate PM emissions models.	H4. Evaluate control strategy programs.
Medium	M7. Improve PM measurements.[a] M8. Increase the spatial extent and temporal resolution of PM measurements.[a]		M1. Collect information on fugitive dust emissions.[b] M5. Evaluate roadway project effects on emissions. M9. Collect exhaust emissions from gross-emitters.[a]	M3. Create short-term MOBILE6.2 fixes. M6. Improve information for MOBILE6.2 users regarding default assumptions.[a] M10. Estimate uncertainty in the emissions/planning/air quality process.[a]	M2. Compile a compendium of control strategy information. M4. Create a data information repository for MPOs/DOTs.
Low		L1. Support model evaluation and improvements. L4. Determine contribution of mobile sources to ambient PM concentrations. L6. Provide adequate data to support air quality model evaluation.	L2. Improve information on ultrafine particles in exhaust. L7. Collect exhaust emissions for non-gross-emitters. L7. Evaluate dilution issues for condensable mass.	L5. Develop models for ultrafine particles. L7. Ensure that hot-spot and air quality models start where emissions models end.	L3. Develop guidance for weighing offsetting air quality and transportation goals (ozone, PM, air toxics, safety, and mobility).

[a] Priority was rated low by MPO and DOT participants.
[b] Priority was rated high by MPO and DOT participants.
[c] The characterization topic area includes references to air quality or receptor models, tools that are typically used by air quality management agencies, rather than by MPOs or DOTs.

The research timeframes listed in **Table 5** were designated using several criteria. First, projects based on analyses of existing data and literature were assumed to be appropriate for near-term completion (i.e., in one to two years). Second, projects that required field work, other primary data collection, or model development efforts were generally expected to take at least three years to complete. Third, projects that involved development of new modeling tools based on data that had not yet been collected were assumed to take six or more years. Most research could span an array of options depending on the funding available and the depth of data collection and analysis anticipated; in many cases, Table 5 identifies a time range (e.g., short to medium) to reflect the range of research options available. It should be noted that some topics, such as monitoring near roadways or measuring emissions profiles from gross-emitters, cannot be fully resolved while vehicle and fuel technologies continue to change substantially (e.g., diesel emissions after 2007).

During the workshop, it became clear that the MPO-DOT workshop participants were especially interested in identifying those research issues that could be completed relatively quickly to aid them in addressing near-term conformity requirements. As shown in Table 5, short-term research topics (medium or high-priority) include

- Compile a compendium of control strategy information.
- Create short-term "fixes" applicable to MOBILE6.2 (fixes refer to improvements that could correct important PM-related deficiencies, such as the lack of speed-corrected heavy-duty vehicle PM emissions).
- Create a data repository or information archive (web site) for MPOs and DOTs.

Table 5. Priority and timeframe for medium- and high-priority research topics.

Research topic (Number refers to numbered topic listing in Table 4)	Estimated Timeframe[a]
H1. Monitor near roadways	Medium to Long
H2. Evaluate hot-spot models	Short to Medium
H3. Develop and evaluate PM emissions models	Medium to Long
H4. Evaluate control strategy programs	Medium
M1. Collect fugitive dust emissions information	Medium
M2. Compile a compendium of control strategy information	Short
M3. Create short-term fixes for MOBILE6.2	Short
M4. Create a data information repository for MPOs and DOTs	Short
M5. Evaluate roadway project effects on emissions	Medium to Long
M6. Improve information on MOBILE6.2 defaults	Short
M7. Improve PM measurements	Medium to Long
M8. Increase spatial extent and temporal resolution of PM measurements	Medium to Long
M9. Collect exhaust emissions from gross-emitters	Medium to Long
M10. Estimate uncertainty in the emissions, planning, and policy process	Short to Medium

[a] Short-term projects are assumed to provide needed information in approximately one or two years, medium-term projects in approximately three to five years, and long-term projects beyond five years; see text for additional detail.

2. RESEARCH NEEDS BY FOCUS AREA

In the 2000 to 2004 PM research plan (Carr et al., 2002a), five research focus areas were identified by the research community and transportation professionals. Five similar research focus areas were used to organize the literature assessment completed to develop this Strategic Plan (Tamura et al., 2005). In the literature assessment, research issues were identified by focus area in tables at the beginning of each section; these tables have been updated in Appendix B of this document to reflect the priority of each need as discussed at the workshop.

This discussion section lists each of the five research focus areas and identifies the high-, medium-, and low-priority research needs in each focus area. Since Sections 3, 4, and 5 of this document are organized by research priority (high-, medium, or low-priority, respectively), this Section is intended to help readers find descriptions of research needs by focus area. More complete descriptions of important research needs are included in the Sections that follow.

2.1 BASIC RESEARCH

- Monitoring. Ambient measurements of PM and precursors at outdoor locations ranging from sites near roadways, to neighborhood scale, to urban scale, or to rural sites. Monitoring in this context does not include emissions measurements.

  Research Needs:

  - High. Monitor near roadways.
  - Medium. Improve PM measurements. Increase the spatial extent and temporal resolution of PM measurements.
  - Low. None

- Characterization. The use of air quality or source receptor models and methodologies to relate ambient concentrations to local emissions sources, upwind sources, and meteorology. These tools are typically used by air quality planning agencies. This topic area does not include the emission or hot-spot models typically used by transportation planning agencies.

  Research Needs:

  - High. None
  - Medium. None.
  - Low. Support air quality model evaluations and improvements. Determine contribution of mobile sources to ambient PM contributions. Provide adequate data to support air quality model evaluation.

- Emissions Measurements. Direct quantification of vehicle emissions using tools such as dynamometers, remote sensing devices, and evaporative emissions sheds. This research focus area was identified as “Transportation Sources” in the 2000 to 2004 PM research plan.

Research Needs:

- High. None
- Medium. Collect information on fugitive dust emissions. Evaluate roadway project effects on emissions. Collect exhaust emissions from gross-emitters.
- Low. Improve information on ultrafine particles in exhaust. Collect exhaust emissions for non-gross-emitters. Evaluate dilution issues for condensable mass.

2.2 APPLIED RESEARCH

- Emissions and Hot-spot Models. Models that are used to calculate the emissions or impact of emissions on ambient air concentrations near roadways. This research focus area was identified as "Modeling" in the 2000 to 2004 PM research plan.

  Research Needs:

  - High. Evaluate hot-spot models. Develop and evaluate PM emissions models.
  - Medium. Create short-term MOBILE6.2 fixes. Improve information for MOBILE6.2 users regarding default assumptions. Estimate uncertainty in the air emissions/planning/air quality process.
  - Low. Develop models for ultrafine particles. Ensure that hot-spot and air quality models start where emissions models end.

- Control Strategies. Measures used to reduce emissions with the intended consequence of improving air quality.

  Research Needs:

  - High. Evaluate control strategy programs.
  - Medium. Compile a compendium of control strategy information. Create a data information repository for MPOs/DOTs.
  - Low. Develop guidance for weighing offsetting air quality and transportation goals (ozone, PM, air toxics, safety, and mobility).

For comparison, the research focus areas, key questions, and proposed projects from the 2000 to 2004 PM research plan are shown in **Appendix C**.

3. HIGH-PRIORITY RESEARCH TOPICS

This section describes in greater detail those research topic areas considered high-priority. Each recommendation is described in order of its rating by participants of the one-day workshop. A brief description of the goals of that research, value to the transportation community, background, and example projects are provided. Four research topics were considered high priorities as shown in Table 3. These research priorities are summarized in **Table 6**.

Table 6. High priority research issues.

Research issue	Monitoring	Characterization	Emissions	Modeling	Controls	Recommendation number from Literature Assessment (Tamura et al., 2005). Also available in Table 1 in this document.
H.1. Monitor near roadways	X					LA-1
H.2. Evaluate hot-spot models				X		LA-16
H.3. Develop and evaluate PM emissions models				X		LA-14
H.4. Evaluate control strategy programs					X	LA-19

3.1 MONITOR NEAR ROADWAYS

Research goals. Provide near-roadway monitoring and traffic data needed to evaluate hot-spot modeling tools, determine concentration gradients of PM and precursors near roadways, and support health effects research. **Figure 4** illustrates a mobile monitoring unit used by the UCLA-based Southern California Particle Center to monitor near-roadway PM concentrations.

Figure 4. Mobile particle instrumentation unit from the UCLA-based Southern California Particle Center Supersite. Photo courtesy of the Southern California Particle Center Supersite.

Value to Transportation Community. The EPA has proposed conformity regulations that could require MPOs and DOTs to estimate the impacts of transportation projects near roadways (i.e., “hot-spot or localized” problems). However, available modeling tools to meet these proposed requirements have not been evaluated against PM monitoring data (see Section 3.2). Data to perform these hot-spot model evaluations are not available from current PM monitoring networks, because these networks are not designed to characterize near-roadway PM or PM precursor concentrations. Near-roadway monitoring of PM and traffic is needed to provide data to evaluate the modeling tools and ensure that they accurately predict PM concentrations. Near-roadway monitoring data can also be used to

- assess the effects of congestion mitigation and control strategies on near-roadway PM concentrations,
- evaluate the effects of driving conditions (speed, fleet composition, etc.) on near-roadway PM concentrations,
- understand fundamental physical and chemical transformations of PM from mobile source emissions, and
- provide data to support health effects research.

Background. A growing body of literature shows that morbidity, mortality, and cardiopulmonary outcomes are a function of inverse distance to major roadways, traffic density, and type of traffic (i.e., gasoline/diesel vehicle split). For example, epidemiological studies have linked exposure to traffic with asthma, stroke mortality, and decreased life expectancy (Wjst et al., 1993; Nicolai et al., 2003; Duki et al., 2003; Hoek et al., 2002a; Roemer and van Wijnen, 2001b). However, there are no definitive studies identifying which pollutants (i.e., gases, particles, ultrafine particles, or mixtures of pollutants, etc.) are responsible for the health effects.

Monitoring studies have shown only slightly elevated concentrations of PM mass near and on roadways (Roemer and van Wijnen, 2001a; Hoek et al., 2002b; Tiitta et al., 2002; Wu et al., 2003; Harrison et al., 2003; Etyemezian et al., 2003; Weijers et al., 2004; Zhu et al., 2002b; Zhu et al., 2002a). Near-roadway concentrations of black carbon, CO, and particle number are more elevated. (e.g., Sardar et al., 2004; Fine et al., 2004; Zhu et al., 2002b; Zhu et al., 2002a).

Example Projects. In designing "near-roadway" monitoring projects, the following objectives should be considered:

- Multiple monitors will be necessary to characterize PM concentration gradients. Use of a mobile platform with real-time particulate monitors may also be valuable in characterizing such gradients. Not all research goals can be met with a single sampler at one location.
- Multiple samplers may be necessary at each monitor to characterize different chemical components of PM and its precursors. Chemically speciated PM monitoring data would be helpful for identifying the relative amounts of exhaust PM and fugitive PM (i.e., resuspended road dust, brake wear, and tire wear).
- Measurements of size distributions are needed to characterize spatial gradients for PM_{10}, $PM_{2.5}$, and ultrafine particles to support model development and evaluation.
- Chemical speciation of PM components for various size ranges should be considered as well, since the toxicity may be determined by a combination of chemical and physical factors.
- It may be more cost effective to leverage near-roadway studies to include measurement of several pollutants of interest, such as mobile source air toxics, tracer compounds to detect diesel emissions, carbon monoxide (CO), black carbon, and ultrafine particles.
- Collecting traffic data will aid transportation and air quality personnel in evaluating the impacts of congestion mitigation on tailpipe and fugitive PM emissions (see Sections 4.1 and 4.6).

For example, a near-roadway monitoring study could be designed to evaluate the effects of congestion mitigation and control strategies on vehicle emissions. Monitoring concentrations of PM and its precursors near a specific roadway before and after control strategy implementation may allow quantitative evaluation of control strategy efficacy. Data from this type of study could be used to evaluate air quality impacts on a number of pollutants (e.g., PM, PM precursors, air toxics, or ozone precursors) to identify benefits for a range of air quality problems.

3.2 EVALUATE HOT-SPOT MODELS

Research goals. Evaluate hot-spot (i.e., localized) models for their ability to predict PM concentration gradients near roadway intersections and free-flowing roadways. **Figure 5** illustrates hot-spot modeling results based on the CAL3QHC model.

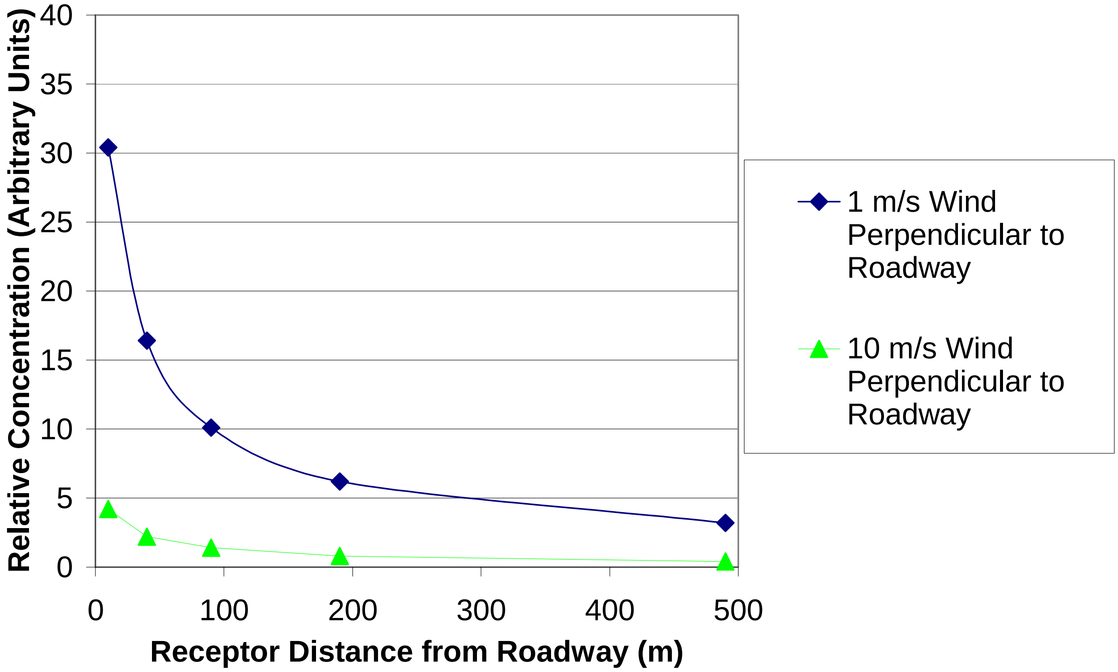


Figure 5. Predicted downwind pollutant concentrations as a function of wind speed and distance from the roadway from the EPA's CAL3QHC model, not including background concentrations. Reprinted from Tamura and Eisinger (2003).

Value to Transportation Community. The EPA has proposed conformity regulations that could require MPOs and DOTs to estimate the impacts of transportation projects near roadways (i.e., "hot-spot or localized" problems). However, available modeling tools used to meet these proposed requirements have not been evaluated against PM monitoring data. It is well established that PM concentrations can be higher in the vicinity of roadways (see Section 3.1). MPOs and DOTs will need modeling tools that accurately predict PM concentrations at monitors near roadways as a function of distance, and will need to understand what factors significantly influence the model results.

Background. Hot-spot modeling tools are vital for completing environmental impact reports and project-level analyses. During the one-day workshop, members of the transportation planning community expressed concern that existing modeling tools may be incapable of accurately assessing PM hot-spot problems; they rated this concern as a high-priority.

Historically, hot-spot modeling (and the associated conformity regulations) has focused primarily on CO, which is inert on these spatial scales. Models used for this purpose have incorporated the effects of dispersion due to dilution and air movement, but do not assume any chemical or physical processes take place. In contrast with CO, PM formation and settling processes are not necessarily negligible and fugitive PM may need to be treated separately from exhaust PM (see **Figure 6**).

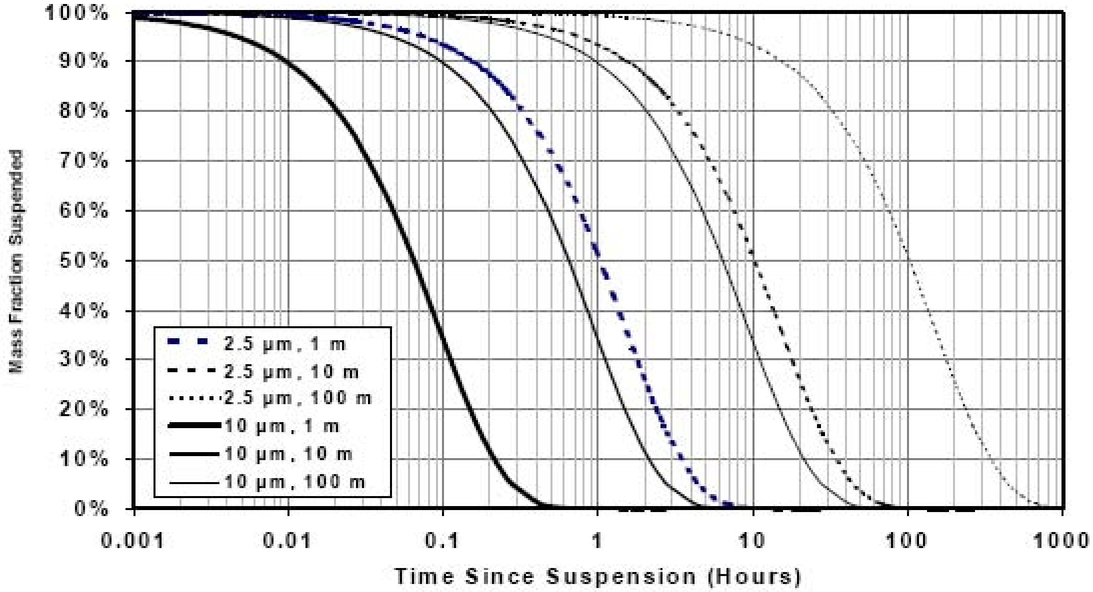


Figure 6. Attenuation of PM_{10} and $PM_{2.5}$ mass concentrations with time and vertical mixing volume. (Reprinted from Countess et al., 2001 with permission.)

EPA regulations for CO hot-spot analyses recommend the use of continuous line-source dispersion models, such as the CALINE model for free-flow roadways and the CALINE-based CAL3QHC model for incorporating queuing at intersections. However, these models perform poorly when the wind is nearly parallel to the roadway (Benson, 1992). The recently developed ROADWAY-2 and HYROAD models showed agreement with measured pollutant concentrations for multiple wind directions (Rao, 2002; Carr et al., 2002b).

Example Projects. Evaluation of localized turbulence and dispersion models has been performed in the past (e.g., Rao, 2002). However, these evaluations have been for inert gas-phase pollutants. Localized concentration gradients of PM need to be evaluated in the same way as in Rao (2002) to determine if deposition and chemical transformation are important. If so, these factors need to be added to the current hot-spot models.

3.3 DEVELOP AND EVALUATE PM EMISSIONS MODELS

Research goals. Develop and evaluate PM emissions models that predict the effect of roadway projects on PM and PM precursor emissions. **Figure 7** reproduces graphics from an FHWA report that illustrate the deficiency of MOBILE6.2 model runs to predict PM emissions variability with speed changes.

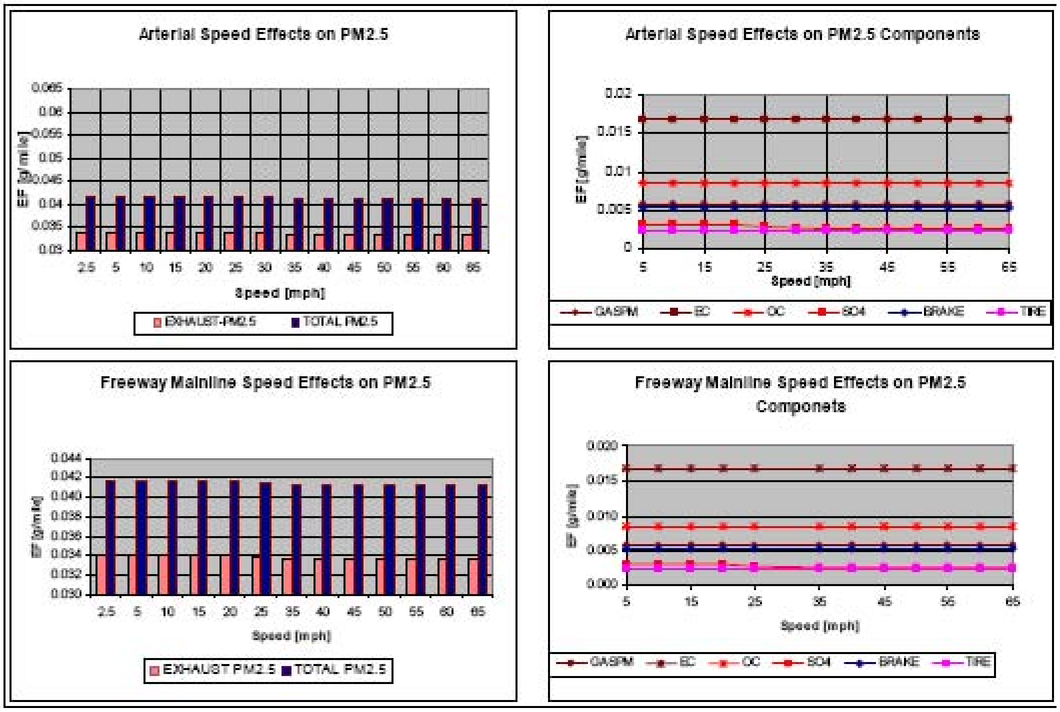


Figure 7. PM emissions as a function of speed from the MOBILE6.2 emissions model. Figure reprinted with permission from Granell et al., (2004).

Value to Transportation Community. Currently, all MPOs and DOTs (except those in California) are required to use the EPA's MOBILE emissions model to calculate emissions budgets to fulfill conformity requirements. For MPO and DOT users, there are two applications of PM emissions models important for transportation conformity assessments: project-level and regional analyses. To complete project-level analysis, emissions are needed for a specific roadway that may be dependent on specific operating modes, and may require sub-hourly output information. Ideally, emissions models for these projects would take into account details such as acceleration (e.g., on-ramp design), grade, and traffic signals. Regional emissions analyses typically focus on assessing average speed and traffic volume information for specific time periods (e.g., morning and afternoon peak periods, and off-peak periods). Regional analyses may need to consider the impact of control measures for conformity, and therefore require the ability to model the effects of available control strategies.

Background. Emissions modeling tools are vital to MPOs and DOTs for completing regional and project-level analyses. During the one-day research workshop, members of the transportation planning community expressed concern that the existing version of the MOBILE model does not include needed emission factor resolution to accurately estimate on-road PM emissions. For example, concern was expressed regarding the lack of speed-corrected heavy-duty diesel vehicle (HDDV) PM emissions. Because HDDV emissions are thought to contribute a large fraction of transportation-related PM, omitting speed correction factors may result in inaccurate model emissions. Transportation planning community participants considered this problem to be a high priority.

The NRC recommended the EPA assess and identify the levels of accuracy needed for the different mobile source emission model applications (National Research Council, 2000); this task has not yet been completed. Without evaluation of the accuracy needs for emissions model applications, it is not clear if the emissions budgets used to develop SIPs and future emissions budgets are realistic or achievable.

MOBILE calculates emission factors based on ambient temperature, vehicle types, average speed, and other variables. There are several known deficiencies with the MOBILE model:

- MOBILE characterizes vehicle activity in terms of average speed and roadway type only, ignoring the impacts of acceleration or grade on emissions.
- MOBILE emission factors for PM and ammonia are independent of speed and roadway type, and assume no deterioration over time. Speed correction factors and deterioration rates exist in other emissions models (Singh et al., 2003; Ubanwa et al., 2003), but have not been extensively evaluated.
- MOBILE has fixed emission factors for tire and brake wear, independent of driving conditions, based on data dating from the mid-1980s.

In response to recommendations to improve mobile source modeling, the EPA is devoting its resources to developing a new emissions model, named "MOVES", to replace MOBILE, although it is not expected to be available for the $PM_{2.5}$ SIPs due in 2008 (Koupal, 2005). Notwithstanding the development of the MOVES model, MOBILE will be used to prepare the next round of 8-hr ozone and $PM_{2.5}$ SIPs, and will therefore be used to establish 8-hr ozone and $PM_{2.5}$ conformity emission budgets. Thus, the transportation community has a longer-term vested interest in correcting known MOBILE model deficiencies.

The MOVES model will address some of the deficiencies in MOBILE by characterizing vehicle activity using vehicle specific power (VSP) rather than average speed. MOVES model development is being evaluated by CRC Project E-68, but it is likely that the transportation community will desire additional evaluations that are specific to highway projects and conformity applications (Lindhjem et al., 2004).

Example Projects. For the development and evaluation of emissions models, example projects could include

- Several project-level PM emissions models have been developed (Singh et al., 2003; Rakha et al., 2003; Barth et al., 2004; Los Alamos National Laboratory, 2004; Fomunung et al., 2000). Model results from these different models should be compared to one another and to the results from emissions testing. Of particular importance is the need to adjust PM emissions depending upon vehicle speed and activity (e.g., free-flow travel at a given speed, compared to more transient operations of the same average speed).
- PM emissions predictions from MOBILE should be compared to results from the in-development MOVES model. If the new MOVES model predicts much lower or higher PM emissions than the original MOBILE predictions, it may become an important policy

issue for emissions budgets or conformity determinations, particularly if the conformity determinations are based on emission budgets created using the MOBILE model.

3.4 EVALUATE COSTS AND BENEFITS OF CONTROL MEASURES

Research goals. Identify and evaluate control measures with incomplete information on costs, benefits, or other knowledge gaps for PM and other air pollutants. **Figure 8** illustrates example control measure situations.

Figure 8. Collage of control measure situations. High occupancy vehicle lanes in Denver (left—courtesy of The Regional Transit District-Denver, CO), bike lane in San Francisco (center—stock photo courtesy of San Francisco Metropolitan Transportation Commission), and fugitive dust in Nevada (right—photo courtesy of Business Environmental Program of Nevada).

Value to Transportation Community. Transportation planners often work with their air quality agency partners to adopt and implement control measures to reduce mobile source emissions. Choosing the appropriate control strategy for a region requires knowledge of the costs and benefits of each measure. This research topic will identify and evaluate control measures with incomplete or missing cost and benefit information to provide policymakers with the necessary details to make informed policy choices. This research topic at least partially depends on the compilation of control strategies (see Section 4.2) and would benefit from an up-to-date on-line repository (see Section 4.4).

Background. Control measures come in many different forms and can have varying efficacy and costs. Control measures can be grouped into at least six different areas:

1. Technology-based controls – controls implemented on new vehicles, such as alternative fuel-use vehicles or hybrids
2. Retrofits – technologies used to reduce emissions on existing vehicles
3. Inspection and Maintenance – checks on the in-use vehicle fleet to reduce the number of vehicles emitting above allowable levels
4. Fuels and lubricants (including additives) – changes to fuels or lubricants that reduce emissions for in-use vehicles

5. Transportation demand management – programs implemented to alter transportation usage, such as rideshare, car pools, high occupancy vehicle lanes, and bike paths
6. Transportation system management – programs designed to change the flow of vehicles, such as left-turn lanes and traffic signal light synchronization.

Comparisons of cost-effectiveness evaluations for air pollution controls vary across orders of magnitude (Wang, 2004; Wang, 1997; Transportation Research Board, 2002). A large amount of the variability in these evaluations was due to differences in evaluation methodologies, which are often not specified or incorrectly applied (Cambridge Systematics, 2001). Since cost methodology guidance is not available for mobile source control strategies, different approaches have been taken. For example, some cost methodologies are based on costs to consumers, while others are based on costs to manufacturers. Implementation costs are often excluded, particularly with respect to those incurred by regulatory agencies (i.e., regulatory development and enforcement). In addition, some measures, such as emissions abatement devices, may be less effective at the local or regional level because of interstate and inter-regional travel.

Example Projects. One possible project would be to identify popular ozone control strategies that reduce VOC or nitrogen oxide (NO_x) emissions with incomplete cost-effectiveness information for PM. These could then be analyzed for their efficacy for reducing PM and PM precursors as well.

A specific control measure evaluation could be to further investigate the efficacy of operating street sweepers. Some studies have questioned whether sweepers are beneficial (e.g., Etyemezian et al., 2005).

Analyses should provide sufficient information to assess the costs and benefits of each control strategy for PM and precursors, as well as for other pollutants like ozone precursors and mobile source air toxics where applicable.

4. MEDIUM-PRIORITY RESEARCH TOPICS

This section identifies and describes research topic areas considered medium priorities by workshop participants. These medium-priority topics were considered medium priorities by either the whole group of workshop participants, by the MPO-DOT workshop participants, or by one of the discussion sections (if the topic was not discussed by all participants). Each recommendation is described in the order in which it was prioritized by participants of the one-day workshop (see Tables 2 and 3). A brief description of the goals of that research, its value to the transportation community, and additional background information is given for each research topic. Multiple research topics were considered medium priorities as shown in Table 4. These research priorities are summarized in **Table 7**. Table 7 includes three medium-priority research needs that were identified by workshop participants but not included in the PM literature assessment (Tamura et al., 2005).

Table 7. Medium-priority research issues.

Research issue	Monitoring	Characterization	Emissions	Modeling	Controls	Recommendation number from Literature Assessment (Tamura et al., 2005). Also available in Table 1 in this document.
M.1. Collect information on fugitive dust emissions			X			LA-12
M.2. Compile a compendium of control strategy information					X	LA-18
M.3. Create short-term MOBILE fixes				X		New
M.4. Create a data information repository for MPOs and DOTs					X	New
M.5. Evaluate roadway project effects on emissions			X			LA-9
M.6. Improve information for MOBILE users regarding default assumptions				X		LA-13
M.7. Improve PM measurements	X					LA-2
M.8. Increase the spatial extent and temporal resolution of PM measurements	X					LA-3
M.9. Collect exhaust emissions from gross-emitters			X			LA-8
M.10. Estimate the uncertainty in the planning/emissions/air quality process				X		New

4.1 COLLECT INFORMATION ON FUGITIVE DUST EMISSIONS

Research goals. Understand and resolve gaps between fugitive dust emissions data and ambient concentrations near roadways. Determine possible dependency of fugitive dust emissions on speed and other parameters.

Value to Transportation Community. Resolving the discrepancy between fugitive dust emission inventory estimates and ambient concentrations may reduce the assumed need for costly fugitive dust control strategies in some areas. This research may also help existing or future models predict fugitive dust emissions from mobile sources with more accuracy.

Background. Fugitive dust can be a dominant component of PM emissions inventories, especially for larger sized particles such as PM_{10}. EPA calculation methodologies attributed essentially all PM_{10} and $PM_{2.5}$ emissions near roadways to fugitive dust prior to 2003 (U.S. Environmental Protection Agency, 2003). However, source apportionment of ambient concentrations have shown that fugitive dust is not as large of a contributor as emissions would indicate for PM_{10}, and fugitive dust is a small component of $PM_{2.5}$ (Watson and Chow, 2000; Countess et al., 2001; Fitz, 2001).

The EPA's paved road fugitive dust emission model contains a number of unrealistic assumptions about fugitive dust emissions. This model depends solely on vehicle weight and roadway silt loading, does not incorporate any dependence on speed, and is only applicable to vehicles of at least two tons driving at speeds of 10-55 mph. Researchers have shown that speed can significantly influence fugitive dust emissions (Langston, 2004).

4.2 COMPILE A COMPENDIUM OF CONTROL STRATEGY INFORMATION

Research goals. Compile and maintain an updated compendium of mobile source PM control measures for the transportation community.

Value to Transportation Community. A comprehensive compilation of control strategies with consistent evaluation of costs and benefits would provide transportation and air quality practitioners with an excellent resource for choosing the appropriate control strategy for their region. In addition, this research topic would help to identify which control strategies need additional evaluation of costs and benefits (see Section 3.4), and would be an excellent example of information that could be placed in an information archive for DOTs and MPOs (see Section 4.4).

Background. MPOs and DOTs need reliable information regarding control strategies, including the consequences for other air quality and transportation goals. Several control measure evaluations have been conducted, but evaluations have significant discrepancies due to methodological inconsistencies, or provide limited results. A few compilations of PM control strategies are currently available. These compilations include

- Mobile-source related PM control strategies (STAPPA and ALAPCO, 1996).
- A beta-test software tool to calculate costs and emission reduction benefits for any region of the United States (E.H. Pechan and Associates, 2003).

- PM_{10} control strategies for primary emissions (Maricopa Association of Governments, 1999; Sierra Research, 1998).
- Diesel PM emissions control measures (e.g., Berman et al., 2002; Diesel Stakeholders Work Group, 2002).

4.3 CREATE SHORT-TERM MOBILE FIXES

Research goals. Create near-term patches for MOBILE to improve mobile source emissions estimates for the first round of PM conformity and SIP planning.

Value to Transportation Community. Regulatory guidelines require DOTs and MPOs to begin the $PM_{2.5}$ conformity process one year following EPA designation of nonattainment areas, and require SIPs to be submitted for nonattainment areas by 2008. The new MOVES emissions model will not be available in time for DOTs and MPOs to use in the initial round of conformity and SIP development. In order to more accurately predict mobile source emissions for the initial round of $PM_{2.5}$ conformity, short-term patches to the most serious problems in MOBILE should be added.

Background. MOBILE is the required emissions model most MPOs and DOTs use to calculate regional and project-level emissions, yet it has large uncertainties for its estimates of PM emissions. For example, when modeling heavy-duty diesel vehicle emissions, MOBILE does not vary PM emissions by speed. As mentioned in Section 3.3, MOVES is the new emissions model being developed by the EPA to replace MOBILE. MOVES will have a modal structure that will be more physically realistic in its prediction of PM. Since there is a regulatory requirement to use MOBILE for conformity determinations, it will be important to have any patches for MOBILE approved by the EPA for use in conformity determinations.

4.4 CREATE A DATA INFORMATION REPOSITORY FOR THE TRANSPORTATION COMMUNITY

Research goals. Create and maintain an up-to-date information repository, such as a web site, for the transportation community.

Value to Transportation Community. A well-maintained web site with PM-specific data and information could be of benefit to transportation planners. Key information in such a repository could include

- A list of control strategies
  – relevant literature describing the control strategies,
  – regions where a given control strategy was implemented,
  – real-world results of the application of the control strategies, and
  – contact information for officials involved in implementation of a given strategy.
- A list of locally created emissions or activity information for MOBILE or MOVES.
- Forums for users of modeling tools.

- Other relevant and changing information regarding the conformity process, including lessons learned.

Many of the research topics directly pertinent to the transportation community could be distributed through such a central repository. For example, the compendium of control strategies (Section 4.2), MOBILE fixes (Section 4.3), and guidelines for users of tools (see Section 4.5) could all be included. On-line discussion forums could allow for exchange of insights concerning the usefulness of information archived, or could facilitate the exchange of advice from previous users of the archived information.

4.5 EVALUATE ROADWAY PROJECT EFFECTS ON EMISSIONS

Research goals. Evaluate how changes in driving speed on a given facility impact emissions.

Value to Transportation Community. Available emissions modeling tools have a limited ability to vary PM emissions by speed because of the lack of adequate speed correction factors. Road grades (particularly for HDDV) and the impact of acceleration/deceleration on PM emissions are also issues for emissions modeling tools. The transportation community needs these models to accurately evaluate the effect of changes in average speed or congestion levels on emissions for conformity determinations.

Background. Emissions in MOBILE have traditionally been based on emissions data by type of trip, rather than data for different speeds on a given facility (e.g., freeway). MOBILE6.2 includes facility-specific speed correction factors for CO, VOC, and NO_x, although further improvements are needed to differentiate arterial and freeway travel behavior. However, additional research is needed to evaluate how facility-specific speed changes affect PM and PM precursor emissions and how to incorporate this information into MOBILE and MOVES. These data are important to the transportation community to evaluate how congestion mitigation and facility choices impact PM emissions on the project and regional levels.

4.6 IMPROVE INFORMATION FOR MOBILE USERS REGARDING DEFAULT ASSUMPTIONS

Research goals. Develop guidance for MOBILE users on which default inputs are most important to replace with local- or region-specific data.

Value to Transportation Community. Choosing local or default inputs to the MOBILE model can significantly impact PM emission predictions. The transportation community needs to know which inputs model results are most sensitive to. This research would provide a prioritized list of user inputs that have the most impact on predicted PM emissions for MOBILE users.

Background. MOBILE model users need to prioritize data collection efforts for model inputs for conformity determinations. Sensitivity analyses have been conducted (e.g., Tang et al., 2003; Granell et al., 2004), but have not identified which of the sensitive inputs can be substantially improved or changed through data collection efforts. The importance of changing default values to local inputs depends on three factors:

- The purpose of the modeling and associated accuracy needs.
- The sensitivity of the model to that input.
- The magnitude of difference between the local and default input.

4.7 IMPROVE PM MEASUREMENTS

Research goals. Improve measurement methods to more accurately measure PM, its components, and PM precursors.

Value to Transportation Community. Improved PM measurements will reduce uncertainty in source apportionment, and improve the ability of SIP strategies to achieve PM NAAQS, and reduce the risk that conformity emission budgets will be set arbitrarily or will need to be substantially adjusted at risk to the conformity process.

Background. Measurement methods to measure PM mass and its components are affected by positive and negative biases due to volatilization or adsorption of semi-volatile PM. Mobile sources are a major source of these semi-volatile species, which may result in PM measurements that may under or over-predict the relative proportion of individual PM components, and, thus, the importance of mobile sources to overall PM problems. Improved measurements of PM mass can help to reduce or correct for these biases.

Improved measurement methods to measure PM components may also help to quantify unique organic chemical tracers. The majority of chemical species emitted by mobile sources are organic compounds, which are difficult to identify and measure individually. These chemical tracers can be used to identify individual emissions sources such as diesel vehicles, gasoline vehicles, woodsmoke, and others. Therefore, improved chemical speciation of PM can be used to more accurately measure mobile source contributions to local or regional PM problems. Findings can also be used to support goals of roadside monitoring (Section 3.1) and emissions and hot-spot model evaluation (Sections 3.2 and 3.3).

4.8 INCREASE SPATIAL EXTENT AND TEMPORAL RESOLUTION OF PM MEASUREMENTS

Research goals. Provide more spatially and temporally resolved monitoring data for air quality models, source apportionment, and roadside monitoring data.

Value to Transportation Community. Increased resolution and spatial distribution of PM monitors and instruments will improve our ability to understand the influence of pollutant transport compared to localized sources and to assess exposures.

Background. Air quality models are used to characterize the contribution of mobile sources to ambient PM, set transportation and conformity emissions budgets, and evaluate control strategy efficacy. Ambient monitoring data from a large number of monitors with sub-daily resolution is needed to evaluate air quality models. These models cannot be rigorously tested using 24-hr average measurements from a few monitors. A large number of high quality measurements are needed to test whether an air quality model is predicting the concentration at the right time for the right reason. In addition, higher resolution data will be needed if comparisons are to be drawn to time periods with varying traffic activity. Also, there is increasing interest in weekend versus weekday pollution episodes, and greater time-resolution of PM data will be needed to distinguish weekend from weekday PM episodes.

4.9 COLLECT EXHAUST EMISSIONS FOR GROSS-EMITTERS

Research goals. Evaluate the frequency and emissions of gross-emitting vehicles in the fleet.

Value to Transportation Community. Accurately assessing and understanding the total emissions from gross-emitters will help improve emissions modeling tools, thus assisting the transportation and air quality communities with creation of conformity emission budgets and selection of appropriate control strategies for reducing emissions.

Background. A small fraction of light-duty vehicles and heavy-duty diesel vehicles may be contributing a very large fraction of the total PM emissions. These vehicles, referred to as gross-emitters, may be the primary targets for control strategies. However, it is difficult to accurately determine the number of gross-emitting vehicles in the fleet or to assess their typical emissions profiles (i.e., a variety of vehicle attributes contribute to determining whether any one vehicle is a gross-emitter; thus, it is difficult to develop a "typical" profile for gross-emitters). Moreover, a gross-emitter of some chemical species such as NO_x may not be a gross-emitter of PM. Gross-emitters are not included in current PM emissions models, but are currently treated in the post-processing stage. Additional evaluation of the fleet composition to determine the percentage of gross-emitting vehicles and their emissions profiles is needed to understand the importance of gross-emitters and to implement control strategies to reduce their numbers. Research is already underway to better evaluate the proportion of on-road PM emissions originating from light-duty versus heavy-duty vehicles, but definitive results have yet to be published, and additional gross-emitter evaluations will help to elucidate the main on-road PM problems.

4.10 ESTIMATE AND REDUCE THE UNCERTAINTY IN THE TRANSPORTATION PLANNING, EMISSIONS ESTIMATION, AND AIR QUALITY MANAGEMENT PROCESS

Research goals. Diagnose and reduce the largest sources of uncertainty in the planning, emissions assessment, and air quality management processes.

Value to Transportation Community. Identifying and reducing the largest sources of uncertainty in the planning, emissions, and air quality process will help transportation and air quality practitioners to better estimate mobile source emissions.

Background. The tools and analysis methodologies used to demonstrate transportation conformity include large uncertainties. Notwithstanding these uncertainties, final conformity approval decisions are made based on a threshold value analysis that may estimate emissions to within hundredths of a ton. The implied precision of these determinations is out of scale with the uncertainties inherent in the tools used to complete the analyses. While the existing approach simplifies the conformity process, it does not adequately reflect the uncertain data and tools used to make the final decision. The unrealistic precision in conformity determinations has left many air quality and transportation planning professionals with the sense that conformity is a "paperwork exercise" contributing little value to transportation planning decisions. Analyzing the uncertainties in the planning, emissions, and air quality modeling process could identify those areas where the largest uncertainties exist. These highly uncertain areas could then be targeted for further research to reduce their uncertainties. The results may help to improve the quality of conformity assessments and enhance the ability of the conformity process to influence transportation planning decisions.

5. LOW-PRIORITY RESEARCH TOPICS

This section lists research topic areas considered low priorities by workshop participants and transportation participants of the workshop. Recommendations are listed here for completeness, but are not described further due to their low priority. For more information on these research recommendations, please see Tamura et al. (2005) and McCarthy et al. (2005). These low-priority research topics are summarized in **Table 8**.

Table 8. Low priority research issues.

Research issue	Monitoring	Characterization	Emissions	Modeling	Controls	Recommendation number from Literature Assessment (Tamura et al., 2005). Also available in Table 1 in this document.
L.1. Support air quality model evaluation and improvements		X				LA-5
L.2. Collect exhaust emissions for non-gross-emitters			X			LA-7
L.3. Develop guidance to simultaneously address different air quality and transportation goals					X	LA-20
L.4. Determine the contribution of mobile sources to ambient PM concentrations		X				LA-6
L.5. Develop hot-spot models for ultrafine models				X		LA-17
L.6. Provide adequate data to support air quality model evaluation and improvements		X				LA-4
L.7. Evaluation dilution of condensable PM mass			X			LA-10
L.7. Improve understanding of ultrafine particles in vehicle exhaust			X			LA-11
L.7. Ensure that hot-spot and air quality model boundary conditions match emission models				X		LA-15

6. FINDINGS

FHWA sought to update its 2000 to 2004 PM research plan (Carr et al., 2002a) to reflect recent scientific findings and to anticipate information needs for the 2005 to 2010 time period. The 2005 to 2010 time period complements the long range PM research portfolio prepared by the National Research Council (National Research Council, 1998).

Preparation of this Strategic Plan completes the third of a three-step process FHWA initiated to update its 2000-2004 PM research plan. The first step of FHWA's effort was to commission an assessment of recent and ongoing PM research and to identify important research gaps (Tamura et al., 2005). The second step was to convene approximately 50 national experts to evaluate the PM assessment document, identify additional research issues, and reach consensus on high-priority PM research issues. The consensus-building process occurred at a one-day workshop held on April 7, 2005, in San Diego, California. Workshop participants included environmental and transportation planners from state and regional DOTs and MPOs; and representatives from air quality agencies, industry, the academic community, and consulting organizations. Workshop findings were documented in a Workshop Summary report (McCarthy et al., 2005).

The main contribution of FHWA's effort has been to achieve broad consensus across a wide range of stakeholder groups that four transportation-related PM research issues are of highest priority for the 2005 to 2010 time period. High-priority research issues include

- monitoring near roadways,
- evaluating PM hot-spot models,
- developing and evaluating PM emissions models, and
- evaluating control strategy programs.

In addition to the high-priority research needs, the work has also identified a variety of medium and lower priority research needs.

Members of the MPO-DOT community expressed that, among these additional research needs, several research efforts that could be completed in the near-term were especially important. These include

- Compile a compendium of control strategy information.
- Create short-term "fixes" applicable to MOBILE6.2 (fixes refer to improvements that could correct important PM-related deficiencies, such as the lack of speed-corrected heavy-duty vehicle PM emissions).
- Create a data repository or information archive (web site) for MPOs and DOTs.

FHWA intends to work with its partner agencies and with other stakeholders to provide funding or other forms of support for these priority research efforts. Completion of these research efforts will advance understanding about the relationship between on-road mobile sources and PM problems, provide improved analysis tools for SIP and conformity analyses, and facilitate identification and implementation of effective PM control strategies.

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APPENDIX A

APRIL 7, 2005, FHWA PM WORKSHOP PARTICIPANTS

Table A-1. List of April 7, 2005, FHWA PM workshop participants by organizational category.

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MPO's/DOT's	State and International Agencies	EPA	Industry	Research Community	FHWA	STI
Kip Billings Wasatch Front Regional Council	Scott Fruin California Air Resources Board (CARB)	Chad Bailey	Brent Bailey CRC	Gary Bishop University of Denver	Kevin Black	Lyle Chinkin
Mike Brady Caltrans	Lisa Graham Environment Canada	Richard Baldauf	Tim Belian Coordinating Research Council (CRC)	Ed Carr ICF Consulting	Michael Claggett	Doug Eisinger
Beverly Chenausky Arizona DOT	Tom Lanni New York State Department of Environmental Conservation (NYSDEC)	Rudy Kapichak	Steven Cadle General Motors	Judith Chow Desert Research Institute (DRI)	Cecilia Ho	Hilary Hafner
Cora Cook Georgia DOT	Hector Maldonado CARB	Edward Nam	King Eng Shell Global Solutions	Nigel Clark West Virginia University	Jeff Houk	Michael McCarthy
Amy Costello Virginia DOT			David Hyder The Louis Berger group	Rob McConnell USC School of Medicine	Michael Savonis	Paul Roberts
Rob Goodwin Georgia Regional Transit Authority			David Lax American Petroleum Institute (API)	Maria Costantini Health Effects Institute		

Table A-1. List of April 7, 2005, FHWA PM workshop participants by organizational category.

MPO's/DOT's	State and International Agencies	EPA	Industry	Research Community	FHWA	STI
Chris Klaus North-Central Texas Council of Governments			Shirish Shimpi Cummins, Inc.	Tom Kear UC Davis		
Arnold Sherwood University of California Tech Transfer Program				David Kittelson University of Minnesota		
Kermit Wies Illinois DOT				Doug Lawson National Renewable Energy Laboratory (NREL)		
John Zamurs New York DOT				Peter McMurry University of Minnesota		
				John Watson DRI		
				Arthur Winer UCLA School of Public Health		

APPENDIX B

UPDATED RESEARCH TABLES FROM THE TRANSPORTATION AND PM LITERATURE ASSESSMENT

Tables provided at the beginning of each chapter in the Transportation and PM Literature Assessment (Tamura et al., 2005) listed research issues by broad research category. These research issues were used to create the list of 20 research recommendations in Table 1 of this report. The tables from the literature assessment contained a column called "FHWA priority" that remained blank. The intended use of this column was to allow the workshop participants to prioritize these research issues. These tables have now been updated with the research priorities as identified in Table 4 of this report.

Table B-1. List of monitoring research issues from the literature assessment (Table 2-1 of the literature assessment). Priorities are listed as high, medium, or low (H, M, or L); their number (e.g., M1, M2, or M3) corresponds to the priority research topics identified in Table 4 of this Strategic Plan. NS means the research issue was not selected as one of the low-, medium-, or high-priority research needs in this Strategic Plan.

2. Monitoring issues	Strategic Research Documents[a]	Recently Completed Work	Ongoing or Planned Work	FHWA Priority (as numbered in Table 4)
2.1 Measurement methods				
2.1.1 Improving measurements and characterization of carbonaceous aerosols	NARSTO, CENR	X	X	M7
2.1.2 Improving measurements and characterization of semi-volatile aerosols	FHWA P3, NARSTO	X	X	
2.1.3 Evaluating method accuracy, precision, and comparability for PM measurements	NARSTO, CENR	X	X	
2.2 Monitoring networks and uses				
2.2.1 Identification of $PM_{2.5}$ nonattainment areas	FHWA P1	X		NS
2.2.2 Improving the spatial extent and temporal resolution of PM and precursor monitors and instruments	NARSTO, CENR, NRC	X	X	M8
2.2.3 Integrating transportation concerns into existing monitoring networks	FHWA P2	X		NS
2.3 Monitoring and characterizing PM near roadways		X	X	H1

[a] Project numbers (P#) are identified for areas identified in the 2000-2004 FHWA strategic work plan for PM research; see Appendix C for a summary listing of the 2000-2004 projects.

Table B-2. List of characterization research issues from the literature assessment (Table 3-1 of the literature assessment). Priorities are listed as high, medium, or low (H, M, or L); their number (e.g., M1, M2, or M3) corresponds to the priority research topics identified in Table 4 of this Strategic Plan. NS means the research issue was not selected as one of the low-, medium-, or high-priority research needs in this Strategic Plan..

3. Characterization Issues	Strategic Research Documents[a]	Recently Completed Work	Ongoing or Planned Work	FHWA Priority (as numbered in Table 4)
3.1 Evaluation and improvement of the performance of air quality models	FHWA P9, NARSTO, CENR, EMEP, NRC	X	X	L1
3.2 Understanding transportation emissions contribution to PM concentrations	FHWA P5	X	X	L4
3.3 Updating source profiles used in modeling	FHWA P4, CENR, NARSTO	X	X	NS
3.4 Separating diesel and gasoline PM contributions	CENR	X	X	NS
3.5 Estimating the contribution of transportation to PM exposure		X	X	NS

[a] Project numbers (P#) are identified for areas identified in the 2000-2004 FHWA strategic work plan for PM research; see Appendix C for a summary listing of the 2000-2004 projects.

Table B-3. List of emissions research issues from the literature assessment (Table 4-2 of the literature assessment). Priorities are listed as high, medium, or low (H, M, or L); their number (e.g., M1, M2, or M3) corresponds to the priority research topics identified in Table 4 of this Strategic Plan. NS means the research issue was not selected as one of the low-, medium-, or high-priority research needs in this Strategic Plan.

4. Mobile Source Emissions Measurements	Strategic Research Documents[a]	Recently Completed Work	Ongoing or Planned Work	FHWA Priority (as numbered in Table 4)
4.1 Exhaust Measurement Methodologies				
4.1.1 Measurement of PM mass	NARSTO, NRC	X	X	NS
4.1.2 Measurement of ammonia	NARSTO, NRC	X	X	NS
4.1.3 Measurement of PM properties	NARSTO, NRC	X	X	NS
4.2 Collection of Exhaust Emissions Data				
4.2.1 HDDV emissions	FHWA P6, NRC emissions modeling review	X	X	M9 and L7
4.2.2 Gross-emitting light-duty gasoline vehicles (LDGVs)	FHWA P7, NRC emissions modeling review	X	X	M9
4.2.3 Ammonia	CENR, NRC	X	X	NS
4.2.4 Ultrafines and speciated organics	NARSTO, NRC	X	X	L2
4.3 Collection of Fugitive Emissions Data				M1
4.3.1 Resuspended road surface material	FHWA P8, NARSTO	X	X	
4.3.2 Direct emissions from brake wear and tire wear		X	X	

[a] Project numbers (P#) are identified for areas identified in the 2000-2004 FHWA strategic work plan for PM research; see Appendix C for a summary listing of the 2000-2004 projects.

Table B-4. List of modeling research issues from the literature assessment (Table 5-1 of the literature assessment). Priorities are listed as high, medium, or low (H, M, or L); their number (e.g., M1, M2, or M3) corresponds to the priority research topics identified in Table 4 of this Strategic Plan.

5. Emissions Models and Hotspot Models	Strategic Research Documents[a]	Recently Completed Work	Ongoing or Planned Work	FHWA Priority (as numbered in Table 4)
5.1 Improving Emissions Modeling				
5.1.1 Improvement of model input data	FHWA P10			M6
5.1.2 Development of new models	FHWA P9, P11; NARSTO; NRC emissions modeling review	X	X	H3
5.1.3 Model evaluations	FHWA P9, P11; NARSTO; NRC emissions modeling review	X	X	
5.2 PM Hot-spot Modeling				
5.2.1 Development of hot-spot models		X	X	H2
5.2.2 Evaluation of hot-spot models		X	X	

[a] Project numbers (P#) are identified for areas identified in the 2000-2004 FHWA strategic work plan for PM research; see Appendix C for a summary listing of the 2000-2004 projects.

Table B-5. List of control strategy research issues from the literature assessment (Table 6-1 of the literature assessment). Priorities are listed as high, medium, or low (H, M, or L); their number (e.g., M1, M2, or M3) corresponds to the priority research topics identified in Table 4 of this Strategic Plan.

6. Control Strategies	Strategic Research Documents[a]	Recently Completed Work	Ongoing or Planned Work	FHWA Priority (as numbered in Table 4)
6.1 Control Strategy Compilations and Cost-Effectiveness Analyses				M2
6.1.1 Available compilations	FHWA P12, P13	X	X	
6.1.2 Information quality and cost-effectiveness methodologies		X		
6.2 Evaluations of Specific Control Types				H4
6.2.1 Transportation control measures (TCMs)	FHWA P12-P14	X	X	
6.2.2 Emission control technology retrofits	FHWA P12-P14	X	X	
6.2.3 Replacement of older vehicles with newer vehicles	FHWA P12-P14	X	X	
6.2.4 Use of different fuels and lubricants	FHWA P12-P14	X	X	
6.2.5 Vehicle inspection & maintenance (I&M)	FHWA P12-P14	X	X	
6.2.6 Reductions in fugitive dust from roads	FHWA P12-P14	X	X	

[a] Project numbers (P#) are identified for areas identified in the 2000-2004 FHWA strategic work plan for PM research; see Appendix C for a summary listing of the 2000-2004 projects.

APPENDIX C

PROPOSED PROJECTS FROM THE 2000 to 2004 PM RESEARCH PLAN

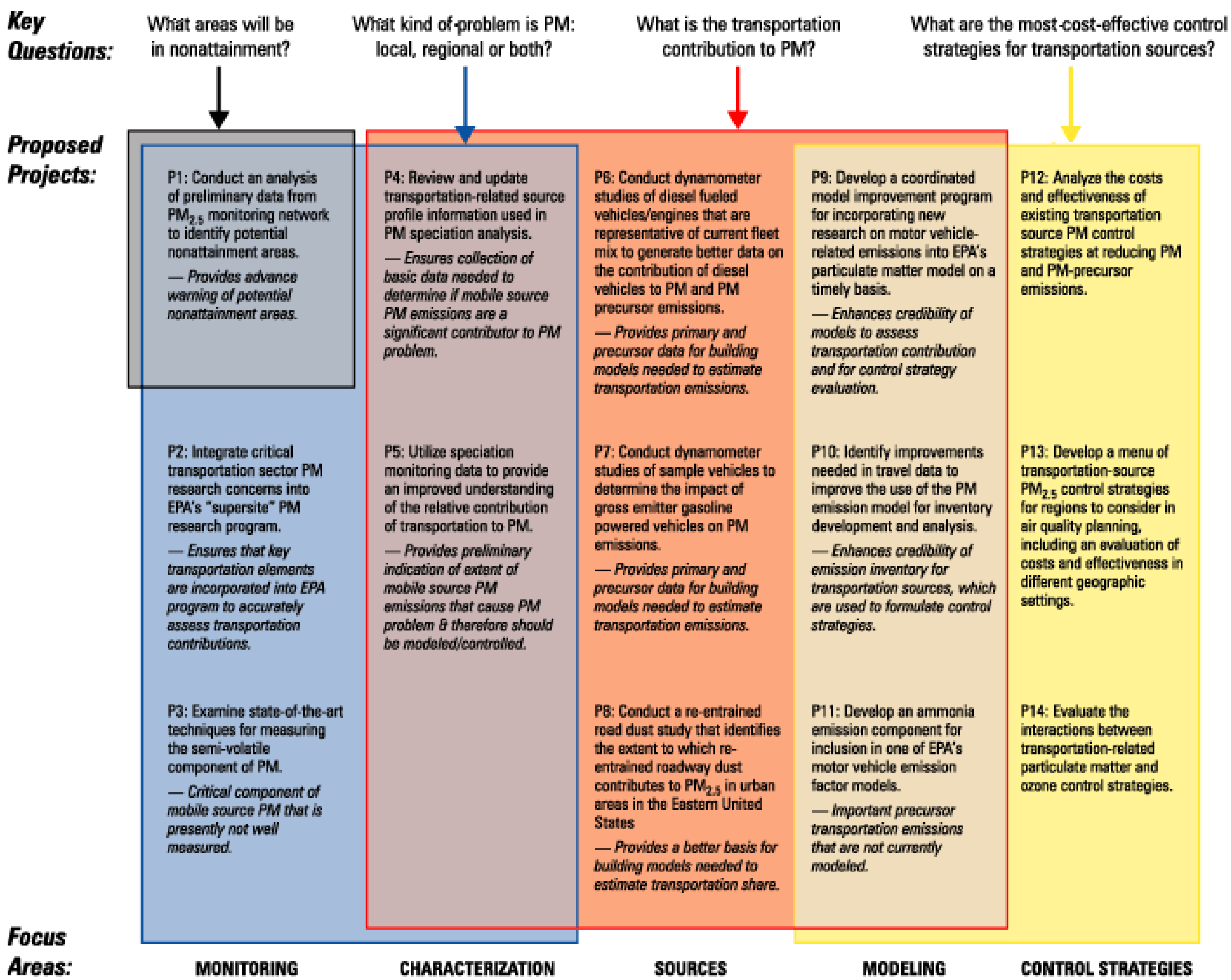

Figure C-1. Connection between transportation issues and research agenda from 2000 to 2004 PM research plan (Reproduced with FHWA permission from Carr et al., 2002a.)