**TRANSPORTATION RESEARCH BOARD**

# ENVIRONMENTAL RESEARCH NEEDS IN TRANSPORTATION

*Report of a Conference*

**ENVIRONMENTAL RESEARCH NEEDS CONFERENCE 2002**

**TRANSPORTATION ENVIRONMENTAL RESEARCH NEEDS STATEMENTS**

TRANSPORTATION RESEARCH BOARD

*OF THE NATIONAL ACADEMIES*

Prepublication Report

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# Environmental Research Needs in Transportation

*Report of a Conference*

**Surface Transportation Environmental Cooperative Research Program Advisory Board**

Washington, D.C.
March 21–23, 2002

*Sponsored by*
Federal Highway Administration, U.S. Department of Transportation
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Transportation Research Board

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
2002
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*Advisers to the Nation on Science, Engineering, and Medicine*

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The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually engage more than 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

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# Transportation Research Board
# Environmental Research Needs in Transportation
# March 21–23, 2002

## Preface

Purpose
Protection of the natural and human environment is a primary responsibility of government agencies responsible for the development, operation, and maintenance of the nation's transportation system. Ongoing research and development is one key to assuring that transportation agencies have the best and most current information, processes, and tools they need to successfully meet their environmental responsibilities. Every 5 years the Transportation Research Board (TRB) conducts a Transportation Environmental Research Needs (ERN) Conference to select and draft top-priority statements of environmental research needs. The most recent of these conferences was held in March 2002, this time with a multimodal perspective. This Proceedings contains the top research needs identified at the conference, along with background papers. These are organized into chapters for each of the following 15 topic areas:

- Air Quality
- Community Impacts, Environmental Justice, and Public Involvement
- Context-Sensitive Design, Including Aesthetics and Visual Quality
- Cultural Resources
- Energy and Alternative Fuels
- Environmental Information Management
- Environmental Streamlining and Stewardship
- Integrated Environmental Decision Making
- Land Use and Transportation
- Noise
- Sustainability, Including Climate Change: Cause and Effects
- Transportation, Human Health, and Physical Activity
- Waste Management and Environmental Management
- Water Quality and Hydrology
- Wetlands, Wildlife, and Ecosystems

This report is published to assist those involved with government, university, and other research programs in selecting research projects that will have the greatest utility for the transportation environmental community.

Conference Process
More than 200 invited environmental experts from around the country assembled for two and one-half days in March 2002 at the TRB's Washington offices and worked collegially to identify research needs. Participants were divided into 15 work groups, each of which represented one of the 15 topic areas previously mentioned. Two moderators led each

work group. After identifying and prioritizing research needs, the groups drafted work statements for the top research needs, including a rough estimate of budget and duration for each statement. These research statements form the main body of this proceedings report and are presented, along with resource papers written in advance of the conference for each topic area.

The research needs statements in this report are the top priorities selected by the participants in each work group from the larger universe of research needs. The statements are not prioritized within the topics, as the members of each work group had diverse perspectives and interests. The participants at the conference wrote the statements, and despite a uniform format and subsequent editing, the statements have differences in style and presentation. The estimates of budget and duration were provided by authors to give a rough measure of the magnitude of each work statement. Finally, the resource papers were provided as background information for participants. For some topics, the perspectives in the papers and the research needs statements may be complementary, for other topics they may be divergent.

<u>Conference Preparation</u>
Conference participants were selected to ensure a balance of professional skills, modal interests, geographic distribution, and organizational interests. Participants included members of state departments of transportation (DOTs), state environmental resource agencies, federal agencies, transportation authorities, universities and research organizations, private nonprofit organizations, and private firms. Participants were nominated by the conference steering committee and the chairs of TRB environmental standing committees.

Starting one year prior to the conference, there was a general call for draft research needs statements. Those contacted included each state DOT, TRB environmental committees, and all those invited to the conference. A general call was also posted on the TRB website. In all, 350 draft statements were received, and these were distributed to conference participants prior to the conference via the Internet and at the conference in electronic format. These draft statements were informational; work groups were free to select from them or draft completely different statements.

Commissioned resource papers were written by experts in each of the 15 topic areas to provide background, context, and a broad sense of research need. These papers represent the views of the authors, but not necessarily those of the participants in the related work groups. The resource papers were distributed to conference participants prior to the conference and are published here to provide a complete record of the conference proceedings.

To assist participants in identifying research already under way, the Center for Transportation and Environment of North Carolina State University prepared a searchable database, Environmental Research in Progress (ENVRIP), which was made available to participants prior to the conference via the Internet.

Two moderators were appointed for each work group in advance of the meeting. They selected the resource paper authors for each group and reviewed the draft papers. Moderators were responsible for assuring that, using a fair and open process, their group identified at least five top research statements and drafted a complete, publishable text for each statement. On the evening prior to the conference, a training session was held for the moderators to review conference objectives and processes.

Each of the 15 meeting rooms was equipped with a printer and a personal computer, loaded with the draft preliminary research needs statements and the ENVRIP database. Conference participants were encouraged to bring laptop computers. The availability of these laptops in each meeting room greatly facilitated composition of the final research statements.

Discussion of Research Needs

The first TRB ERN Conference was held in 1991 and the second in 1996. Comparing the results of these with the 2002 conference illustrates the evolution of the field of transportation and environment and major trends or themes within the field.

1. Research Progress

For some topics, research progresses in an orderly, linear manner, building on prior research completed and expanding to new topics that need exploration. For example, for the Air Quality topic, the 1991 conference proceedings proposed studying emission rates for in-service vehicle operating modes (rather than laboratory tests of new vehicles). This research was funded and a "modal emissions model" was completed. The 1996 conference proceedings proposed expanding detailed study of emission rates to include heavy-duty vehicles, a project that is now underway. The current 2002 proceedings contains statements of research need that would expand the earlier in-service vehicle operating mode research by developing a large, comprehensive sampling plan and database for national use. It also proposes to expand knowledge of emissions from in-service marine vessels and off-road vehicles.

2. Short-Term Research Needs

At the 2002 conference, several groups recognized the need for quick turnaround research responding to immediate research needs. The Energy and Air Quality work groups both included a list of "short-term" projects.

3. Emerging and Changing Issues

A number of new topics emerged in 2002 that were not present at either of the previous two conferences. These included (1) topics of increasing importance, such as Sustainability and Climate Change; (2) new approaches to ongoing processes, such as Environmental Streamlining and Stewardship; and (3) new techniques, such as Context-Sensitive Design and Environmental Information Management. In other cases, similar topics were combined; for example, Community Impacts, Environmental Justice, and Public Involvement.

4. Crosscutting Topics

More than at previous conferences, in 2002, the participants sought to define research that cut across traditional topic boundaries. Initially, work groups were encouraged to communicate freely with each other to avoid duplication of effort. In a number of cases, this communication became formal collaboration on research needs statements of interest to several groups. These collaborative statements are identified in the Table of Contents and the text of the report. Sets of topics producing crosscutting statements include Human Health, Land Use, and Air Quality; Community Impacts, Noise, and Sustainability; and Sustainability, Energy, and Environmental Management. Even when work groups did not make a conscious effort to collaborate, they produced statements relating to other topics. It is therefore important to refer to related topics when searching the Proceedings for research needs.

5. Crosscutting Themes
A reading of all the research statements reveals a number of major crosscutting themes, including

- The importance of public involvement,
- The need for better data,
- The need for evaluation and performance measures to gauge progress,
- The importance of institutional arrangements and the need for better coordination and integration among programs and organizations,
- The importance of fully considering freight transportation in planning and environmental analysis, and
- The emergence of unifying concepts, such as sustainability, stewardship, and environmental management.

<u>Conference Planning, Oversight, and Report Review</u>
The planning for this conference was conducted by an informal Conference Steering Committee chaired by Carol Cutshall, Wisconsin Department of Transportation, and John Fisher, North Carolina State University. The Steering Committee operated under the oversight of the Surface Transportation Environmental Cooperative Research Program Advisory Board. Established in November 1999 by the National Research Council (NRC) and chaired by Elizabeth Deakin, University of California, Berkeley, the Advisory Board was charged to "review and make recommendations for surface transportation environmental planning and energy research, technology development, and technology transfer." In April 2002, TRB released the Advisory Board's report containing its recommendations for research (NRC 2002). Members of the Steering Committee and Advisory Board are listed at the end of this Preface.

It was clear from the outset that the work of the Advisory Board should inform the process and substance of this third ERN effort. Consequently, the Advisory Board served as the parent committee for this activity, charged to help guide conference development and to review the research problem statements developed during the conference for consistency with its own report. Three Advisory Board members—Judith Espinosa, Edwin Herricks, and Wayne Kober—also served on the ERN Conference Steering Committee, to provide liaison and facilitate the sharing of information between the two groups. Advisory Board members were invited to attend the ERN conference, and the Advisory Board reviewed and approved the draft conference proceedings.

Acknowledgments
This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with the procedures approved by the NCR's Report Review Committee. The purposes of this independent review are to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Michael S. Bronzini, George Mason University, Fairfax, Virginia; David L. Greene, Oak Ridge National Laboratory, Oak Ridge, Tennessee; Susan Handy, University of Texas at Austin, Austin, Texas; and Gary R. McVoy, New York State Department of Transportation, Albany, New York.

Although these reviewers have provided many constructive comments and suggestions, they were not asked to endorse the report's content, nor did they see the final draft of the report before its release. The review of this report was overseen by Lester A. Hoel, University of Virginia. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of the report remains with the authoring committee and the institution.

Thanks are due to Joe Shalkowski and Tracy Brown of Michael Baker, Inc., for their work in assembling and organizing both the draft research needs statements and the final resource papers and needs statements included in this document. Thanks are extended to Carol Cutshall and John Fisher and the entire Conference Steering Committee for their leadership in organizing the conference. Finally, special thanks are owed to the session moderators and the conference participants, who worked tirelessly to produce the contents of these proceedings.

This conference would not have been possible without the financial, institutional, and staff support of the Federal Highway Administration, the U.S. Environmental Protection Agency, and the North Carolina State University Center for Transportation and Environment. Other organizations providing valuable support were the American Association of State Highway and Transportation Officials, the Association of Metropolitan Planning Officials, the Federal Transit Administration, and the Surface Transportation Policy Project.

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# Air Quality

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RESOURCE PAPER

# Air Quality

Sarah Siwek, *Sarah Siwek & Associates*

The Clean Air Act Amendments of 1990 (CAA), the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and the Transportation Equity Act for the 21st Century (TEA-21) prompted a surge of new research during the 1990s. Dozens of research projects on the relationship between transportation and air quality and associated topics were completed during the decade. The requirements of the CAA to reduce carbon monoxide, ground-level ozone (urban smog), particulate emissions, and air toxics from motor vehicle engines continue to present challenges to the transportation sector. Nevertheless, tremendous progress has been made in efforts to achieve healthful air, while simultaneously making needed investments to retain and improve mobility and economic vitality. Research needs include fundamental and applied research as well as development, education, technology transfer, and other activities needed to bring about improvements in practice, both in administrative and technical activities. So when we discuss research needs in this paper we are including the above activities in this broader context of research needs. This is especially true because the contribution that research can make to develop expertise is a major consideration given the changing age profile among transportation professionals.

The scope and volume of needed research, including the development of new and improved analytical tools and methods, programmatic research and analysis on topics such as transportation conformity with the National Ambient Air Quality Standards (NAAQS) and the Congestion Management and Air Quality Improvement Program, as well as policy-oriented research on issues such as the growth in vehicle miles traveled, land use, and market-based transportation control measures, has fostered an environment of collaboration in the research community.

During the 1990s, environmental research, and air quality research in particular, became a truly collaborative effort among many parties, including the Federal Highway Administration (FHWA), the Federal Transit Administration, the Environmental Protection Agency (EPA), academic institutions, university transportation centers, and the National Academy of Sciences–Transportation Research Boards' National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP). Given that many agencies and institutions are involved in air quality research and that those resources are limited, it is vital that the collaborative efforts continue through the next decade.

In efforts to ensure coordinated research programs, the FHWA developed a *Strategic Plan for Environmental Research for 1998–2003,* and subsequently developed a *Strategic Workplan for Particulate Matter Research 2000–2004.* By taking a leadership role in identifying and prioritizing research needs and working in collaboration with others, the FHWA has set the stage for critically needed air quality research efforts that help to answer some of the many questions about relationships between transportation and air quality.

In recent years, worldwide concern about global warming has emerged as an area that requires better understanding. In addition, as more information becomes available about air toxics, a new focus on the transportation contribution to air toxics and health effects has emerged. Environmental justice concerns have also been highlighted through a number of studies that seek to understand where the highest exposures to pollutants are and which segments of our population are most impacted by living in areas with high pollutant concentrations.

Highlights of research that have been completed over the past decade include a preliminary assessment of peer-reviewed literature summarizing key findings of the Intergovernmental Panel on Climate Change and the potential implications of global climate change on transportation, cost-effectiveness of transportation control measures, effects of mobile source emissions on health and property, evaluation of the MOBILE6 model and associated studies, Intelligent Transportation Systems Impact on the Environment, etc. The Transportation Research Board publishes "Research Pays Off" articles in its news publication, *TRNews*, and on its website (www.trb.org), and the FHWA Office of Planning, Environment and Real Estate Services website includes a publication on the Research Accomplishments of the 1990s at www.fhwa.dot.gov.

A better understanding of transportation contributions to key pollutants and of strategies that can be implemented to reduce transportation-related pollution continues to be needed. This paper provides an overview of key air quality and transportation research issues and can serve as a foundation for developing specific national research priorities.

## NEW NAAQS FOR OZONE

In July 1997, the EPA promulgated new 8-h ozone and particulate matter standards. Litigation has delayed implementation of the standards and required the EPA to develop a new implementation plan for the 8-h ozone standard. The EPA announced on February 15, 2002, the scheduling of two public meetings to solicit comments on various options to implement the 8-h ozone standard. It can be expected that following these public meetings the EPA will be drafting implementation plans and making decisions on classification schemes for 8-h ozone nonattainment areas. In addition, the EPA will be developing transportation conformity requirements for 8-h nonattainment areas that are expected to affect dozens of new nonattainment areas.

Although some work on the implications of the new NAAQS has been initiated, additional research on the transportation implications of the new ozone standard will be needed and cost-effective strategies to meet the 8-h standards developed. Such strategies should include investigation of measures that nonattainment areas in the ozone transport region can consider to attain the NAAQS. This is a key concern of many areas within the ozone transport region where transport is known to be a major contributor to nonattainment and local options to reduce emissions may be quite limited. Continued work on the assessment of cost-effectiveness of alternative transportation investment strategies is needed in order that policy officials are aware of the trade-offs of different approaches to attaining the new 8-h standard. An 8-h standard will require development of new control measures and strategies in the transportation sector because we are no longer targeting only peak period ozone, but ozone precursors for the full day. Policy implications of the new standard will need to be understood as will the relationship between the attainment plans for the 1-h ozone standard and attainment plans for the 8-h standard. Metropolitan planning organizations (MPOs) and states will need assistance in working through new EPA requirements and improved analytical tools as well as training for staffs in new nonattainment areas will be needed.

### Particulate Matter Research

The EPA promulgated the new fine particulate standards ($PM_{2.5}$) in July 1997 and has implemented an extensive monitoring program for fine particulates. The agency is prohibited from designating new PM areas under this standard until 3 years of monitored data are collected and such designations may occur in the 2004–2006 time frame. The monitoring program is now in place and a better understanding of the extent of pollution from fine particulates is expected to be emerging as data are collected over time. Particulates are a significant contributor to human health problems including asthma, chronic respiratory irritation, toxic exposure, and possible cancinogenesis. Nevertheless, much research is needed to identify what strategies can be implemented to reduce fine particulates. Strategies may also vary by depending on the geographic area in which reductions are needed.

The FHWA recently completed a project to define the transportation community's needs for future research in particulates that will help to define the relationship and contribution of PM emissions from highway vehicles. The FHWA has identified four uncertainties in the current knowledge of PM including: (1) likely nonattainment areas for $PM_{10}$ and $PM_{2.5}$ pollution, (2) whether PM is a regionally or locally produced pollutant, (3) what the transportation contribution is to the total emissions from all sources of PM, and (4) the most effective control strategies for reducing PM emissions. The FHWA then identifies five focus areas for PM research including monitoring, chemical characterization of PM, sources, analysis and modeling, and control strategies. The FHWA *Strategic Workplan for Particulate Matter Research 2000–2004* is a key resource document for needed research in this area. It was developed with the assistance of stakeholders and researchers to promote a coordinated approach to the many critical research needs on particulates. One example of needed research is to develop realistic PM emission factors from construction equipment by activity type, open disturbed areas, and re-entrained dust. Lack of guidance and available methodologies to assess the PM effects of construction activities associated with transportation facilities is an issue. Although we know that construction activities are discrete events that result in elevated PM levels due to emissions from diesel-powered construction equipment, excavation dust, and re-entrained dust, we do not have adequate estimation techniques.

### Global Warming and the Reduction of Greenhouse Gases

The U.S. Department of Energy estimates that carbon dioxide emissions from transportation sources will increase approximately 34% between 1995 and 2010. This means that to reduce "greenhouse gas" (GHG) emissions to 1990 levels as agreed to in the Kyoto Protocol of December 1997 would require a 40% reduction by 2010. Although agreement on how the United States will reduce GHG emissions has not been reached, the concern about greenhouse gases is growing and political pressure for theUnited States to do its part in GHG reductions is increasing. Understanding the relationships between NAAQS criteria pollutants and GHG needs to be improved and strategies identified to simultaneously reduce GHG and primary GHG pollutants. Given the strong correlation between the burning of fossil fuels and GHG emissions, research is also needed to assess the entire approach we use to foster mobility and provide transportation facilities and services in this country. Continued exploration and development of other fuel sources to maintain our mobility while reducing the use of fossil fuels is also needed.

## AIR TOXICS

Another new direction in transportation and air quality research is a focus on air toxics. Studies released by the EPA and others suggest that mobile sources can constitute 30 to 45% of air toxics, and a better understanding of air toxics is needed as well as ways to mitigate air toxic impacts. The impact of air toxics from school buses on the health of children has received renewed attention in a recently released study of the Union of Concerned Scientists. In addition, concern has emerged about environmental justice issues in transportation corridors where air toxics exposure is significant. Although there have been a few studies conducted on air toxics in certain urban environments, there is a definite absence of data on which policy decisions can be made. There is a significant need to obtain information about the contribution of gasoline and diesel vehicles to the ambient air toxics concentrations in all areas including less populated cities and areas having differing climates and meteorological conditions. Based on one study, the Multiple Air Toxics Exposure Study (MATES II), diesel truck and bus emissions may be a significant problem in certain major travel corridors and may increase carcinogenic risk. We need to understand both the short- and longer-term approaches to reducing diesel particulates and the cost-effectiveness of various options. Although new heavy duty engine standards and low sulfur fuels will be phased in later in this decade, the health effects of these pollutants require that we understand as much as possible to appropriately address the health risk.

## NEW MODELS

The recent release of the new generation of EPA's MOBILE model presents new challenges to air quality and transportation planners and modelers. Work is needed to assist planners in adapting to MOBILE6, including collecting necessary region-specific inputs as quickly as possible. Information is needed on the impacts of using region-specific data compared to national default data in transportation conformity analysis, and work is essential to create a database of vehicle- and engine-specific parameters by vehicle manufacturer, make, model, and series, cross referenced to vehicle identification number (VIN). A public domain VIN decoder for use by states and MPOs to develop emission inventories and conformity analysis is needed. In addition, there are a host of other research needs related to improving emission factor models. We also need to understand how MOBILE6 affects the transportation conformity process. Finally, research will be needed to analyze these impacts as use of MOBILE6 is phased in.

MOBILE6 is an interim model intended to transition from the "trip based" emission factors of MOBILE5 to the "modal" emission factors of the New Generation Model (NGM) that reflect driving behavior. It has been established that driving behavior influences emissions as much as the length of time or distance a vehicle is driven. EPA's NGM will be a significant break from current emission factor calculation methods of the MOBILE series of models. It will employ new databases of "in use" vehicle emission data, include calculation of emission factors of off-road vehicles (now handled by the model NONROAD), provide more realistic emission factors for all three levels of analysis (macroscale, mesoscale, and microscale), and interface with transportation and dispersion models. Because of this change, and because EPA's time schedule for releasing it is only 3 years from now (2005 with a test version in 2003), research into the implications of the transition to this new model should be a high priority.

## FLEET CHARACTERIZATION SYNTHESIS

MOBILE6 and California's new EMFAC 2000 require more detailed fleet characterization than has historically been provided. States and MPOs implement the emission rate models with varying levels of detail. Inconsistencies may cause difficulty in developing large-scale regional inventories and determining emissions budgets and effects of transportation control measures. A synthesis of practice across the United States for characterizing vehicle fleet data for use with emission rate models should be developed.

**PROJECT LEVEL ANALYSIS**

The development of MOBILE6 poses challenges to states to perform the required microscale analysis for the National Environmental Policy Act and conformity purposes. Research is needed to identify methods that can be used to generate needed emission factors that can be used at the project level. Such research would enable planners to meet project level conformity requirements and address public concerns of project air quality impacts while using the structure, input, and output of the MOBILE model. Another need is research to identify methods that can be used to generate needed emissions factors that can be used at a project level.

In addition, there is currently lacking systematic air toxic emission data that are necessary for the evaluation of mobile source urban toxic effects at the microscale level. Issues about urban air toxics are currently being raised by some with regards to Environmental Impact Statements and Environmental Impact Reports, yet we have inadequate data to understand how vehicles, drivers, roadway, weather, and facilities affect air toxics. It is essential that a program be developed to obtain the necessary information to answer these questions.

There is an equal need to understand how air toxics generated by transportation and other sources behave at the regional level. What are their transport characteristics and how far do they travel? Such considerations may be crucial to identifying whether and how toxics may disproportionately impact some segments of society.

**NEW VEHICLE AND FUEL STANDARDS**

During the 1990s, the EPA adopted a number of regulations to reduce emissions from motor vehicles. These regulations include the National Low Emission Vehicle rule, the Heavy Duty Engine and Vehicle Standards, and Highway Diesel Fuel Sulfur Requirements. Also, Tier II emissions standards were adopted that will affect all new car sales in the nation starting with model year 2004. The EPA rule to reduce sulfur content in highway diesel fuel will provide substantial emissions reductions. Sulfur in fuels accumulates in the engine's catalytic converter over time and substantially reduces its effectiveness in reducing the engine's emissions. Lower sulfur content will mean lower emissions rates from mobile sources. Combined, the regulations adopted over the past 10 years will substantially reduce motor vehicle emissions. For example, the EPA estimates that as a result of the heavy-duty engine and the related low sulfur rule, $NO_x$ emissions from heavy-duty vehicles will be reduced by 88% from 2007 to 2030, PM reductions are estimated at 64%, and nonmethane hydrocarbons emissions by 11%[1].

The transportation community must continue to monitor and evaluate the implementation of these strategies and ensure that obstacles to implementation are addressed. We continue to need a better understanding of the vehicle fleet, especially that portion affected by the heavy-

[1]Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, Regulatory Impact Analysis (EPA420-R-00-026).

duty engine and fuels rule. For example, we need a better understanding of heavy-duty vehicle activity and to develop best practices for modeling heavy-duty vehicle activity.

### Alternatively Fueled Vehicles
Research into the consumers' decision-making criteria for purchasing new vehicles could be helpful as we work toward developing a more sustainable transportation future. Availability of alternatively fueled vehicles is increasing yet the penetration of the overall fleet with these vehicles is estimated at less than one-tenth of one percent of the fleet. If we are to adopt policies that encourage conversion to alternatively fueled vehicles, we need to better understand consumer behavior and the obstacles to ownership and operation of these vehicles. Research in this area is needed to reduce reliance on fossil fuels.

### Institutional Relationships Between Transportation and Air Quality Agencies
Research is needed to understand how the institutional relationships between transportation and air quality agencies affect a region's ability to reduce transportation-related emissions in cost-effective and publicly acceptable ways. Such research could identify successful institutional frameworks that can be replicated to enhance the dialog and better integrate planning activities of both transportation and environmental agencies. We need to explore whether there are more effective ways to integrate transportation and air quality planning and identify what options are available given our state and local government structures. In addition, policymakers and elected officials continue to require technical information, better decision-making tools, and basic education about the complex interactions between air quality and transportation. Finally, research is needed to understand whether current regulations reward short-term, quick fixes and whether appropriate incentives are in place to encourage long-term, thoughtful planning that can reduce emissions for the long term.

### Strategies to Reduce Emissions
More information needs to be developed and shared about the most cost-effective transportation control measures that could be implemented to reduce transportation-related emissions. Options such as intersector trading of emissions to implement the most cost-effective strategies should be explored. Voluntary programs to reduce diesel emissions from high polluters are being implemented, and we need to understand the cost-effectiveness of these approaches. As the vehicle fleet gets cleaner and cleaner, it may be more cost-effective to reduce emissions from off-road mobile, stationary, or area sources than to implement transportation control measures, which provide only a fraction of the needed reductions in our nation's nonattainment areas. Also, as automobiles get cleaner, the impacts of traditional transportation control measures become even smaller. We need to understand and investigate all options available from the various source categories to accomplish the needed reductions to bring nonattainment areas into attainment and enable maintenance areas to continue to maintain the NAAQS.

### Sustainable Transportation
In recent years an international movement focusing on sustainability and on sustainable transportation has evolved. Much work is needed to understand how we can incorporate land use into transportation decision making. For example, we need to understand the potential tradeoffs between economy, environment, and equity; how existing or new analytical processes will assist us in understanding these relationships; and what institutional issues can be addressed to better

coordinate the activities of those charged with land use responsibility in our towns, cities, and states. Work has begun to educate officials on the connection between land use, urban form, and transportation, but more is needed. In addition, sustainable transportation will require a much greater penetration of our vehicle fleet with alternatively fueled vehicles. Comprehensive regional planning and the integration of transportation, air quality, and land use planning is relatively rare and we need better information on how local officials can play a role in both air quality and transportation planning, and how transportation planning can play a more significant role in land use planning. Short-term effects may be minimal, but it is hoped that in the long term, the integration of land-use, transportation, and air quality planning will transform the way we travel and how frequently we travel by automobile.

## CONCLUSIONS

Although research efforts during the past decade have brought about a much better understanding of the relationships between transportation and air quality, much work remains. The FHWA has developed strategic plans for both environmental research and for particulate matter research (*Strategic Plan for Environmental Research 1998–2003* and *Strategic Workplan for Particulate Matter Research 2000–2004*), which can guide the identification of specific research needs. Additional work in the areas of global warming, air toxics, and environmental justice and air quality is needed and will be high-visibility research issues over the next several years. In addition, we need to continue the work on improving our understanding of vehicle activity, emission factors models, and in developing estimation techniques useful at a project or corridor level. An emerging interest in sustainability and sustainable transportation will encourage more research into fundamental questions about how transportation can best serve the interests of society from an environmental, economic, equitable, and intergenerational perspective. The need to revisit the cost-effectiveness of traditional transportation control measures is upon us as the on-road vehicle fleet continues to become cleaner over time and these measures become less and less cost-effective. Finally, best practices in institutional arrangements that promote the integration of transportation, air quality, and land-use planning could be documented and widely distributed to transportation, air quality, and land use decision makers.

RESEARCH NEEDS STATEMENTS

# Air Quality

## 1. Fine Particulate Matter Pollution: Understanding the Pollutant and Transportation Sources, Developing Models for Regulatory Purposes, and Identifying Control Strategies

**Problem Statement**
Research has identified fine particles of 2.5 microns and less in diameter ($PM_{2.5}$) as a significant contributor to health problems, including asthma, chronic respiratory irritation, toxic exposure, and possible carcinogenesis. Recent reports suggest that as many as 30,000 premature deaths annually are due to fine PM. The EPA is expected to implement a new $PM_{2.5}$ standard in 2005, providing an opportunity for the transportation community to prepare for the upcoming significant regulatory requirements. Fine PM nonattainment areas will be required to meet the conformity provisions under the Clean Air Act, which can cause disruptions in federal funding and misdirected investments from inaccurate modeling. In addition, imposition of more stringent emission standards and controls will result in substantial costs for engine and vehicle manufacturers, petroleum producers, and owners and operators of commercial trucks. Transportation activity is implicated as a major source of these fine particles both through emissions coming directly from the tailpipe and other primary sources, as well as secondary formation in the atmosphere. Several organizations are conducting research into fine PM; however, many factors relating to the characterization and sources have yet to be fully uncovered. Furthermore, reliable predictive models are not available, nor have effective control strategies been developed. It is anticipated by the EPA and the White House Office of Science and Technology Policy that a long-term, major research effort is required so that we can address this pressing need. Finally, as the understanding of PM pollution evolves, it is possible that ultrafines (1 micron and below) may ultimately prove to be the larger health threat, and research efforts to address $PM_{2.5}$ should include some level of effort on ultrafine PM.

**Proposed Research**
A major three-part research effort is proposed to prepare the transportation community to meet its statutory requirements.

*Part 1: Further Characterization and Identification of Transportation Sources of Fine PM*
Building on research from NCHRP 25-18, the FHWA, and other efforts, further research is necessary to determine the local versus regional nature of $PM_{2.5}$, the magnitude of secondary formation of fine PM, and the extent to which $PM_{2.5}$ is transported from one region to another. Basic research shall be conducted to test the robustness of previously reported relationships among the contributions by diesel combustion; gasoline combustion; re-entrained dust; tire, brake, and engine wear; and de-icing sand/salts. Furthermore, research shall be conducted to assess how these might differ by on-road operations (e.g., speed/acceleration/deceleration profiles) and other in-use characteristics, including an attempt to identify differences among fuels and engine displacements using bench testing, as necessary.

*Part 2: Model Development*
Current modeling practice is inadequate to develop emission inventories, make conformity determinations, and determine optimal investment strategies for control. This effort involves a series of phases where analytical techniques and models would be enhanced as the understanding of the issues increases. Given the local versus regional nature of the pollutant (see Part 1), improved microscale models must also be developed.

*Part 3: Identification of Control Strategies*
No area in the country has experience in controlling fine PM from transportation sources. A synthesis of reasonably available control technologies, including those already in ozone control strategies and state implementation plans, should be developed. Recommended control strategies should take into account the needs and expertise of the stakeholders in the transportation community. Control strategies should account for the nature of the transportation contribution, cost-effectiveness, climatic and soil considerations in source apportionment, and compatibility with other air quality strategies. Research would include identification of cost-effective controls that target the most important contributors. Vesting of and cost sharing by the EPA in this project is encouraged.

**Cost:** $5,000,000–10,000,000
**Duration:** 60 months

## 2. Collection of Real-World On-Road Emission Rate Data to Support Ongoing Model Development

### Problem Statement
All air quality-planning efforts depend on the accuracy of a vehicle emissions estimation process. Given the critical infrastructure decisions that rely upon modeling efforts, totaling billions of dollars per year, the existing emission testing database is woefully inadequate.

The vast majority of vehicle emission rate data currently available through public agencies for model development efforts were collected through laboratory testing programs. In these laboratory programs, vehicles are tested on dynamometer driving cycles designed to reflect on-road activities. Government data collection efforts have declined significantly in the last few years, due to a decrease in federal resources dedicated to testing efforts. Hence, insufficient data are available to accurately reflect the on-road emission rates from more recent model year vehicles and older vehicles that have continued to age. Furthermore, concerns regarding the applicability of laboratory data to reflect on-road emissions are significant. New modal emission rate models, developed from second-by-second data collected in laboratories, are predicting emissions as a function of vehicle operating modes. Hard accelerations, high speeds, engine starts, and other modal activities that affect vehicle load are incorporated into these new modal models. Test results indicate that emissions are highly variable across vehicles for the same test condition, as well as across tests for the same vehicle. Hence, large amounts of data are required to develop reliable modal emission rate models. Given the significant decline in emissions testing, greatly expanded resources are needed to bolster the data to support both state-of-the-practice and next-generation modeling efforts. The assembly of quality-assured, quality-controlled data, with associated vehicle technology and actual on-road operating variables, would significantly benefit emissions modeling and estimation efforts.

Onboard technologies are currently available to monitor real-world emissions and to collect associated operating data.

**Proposed Research**
The researchers will develop and implement a comprehensive sampling plan to collect representative second-by-second on-road emission rate data for National Ambient Air Quality Standard (NAAQS) criteria pollutants, $CO_2$, $CH_4$, toxic air contaminants, $NH_3$, and $NO_2$, across light-duty and heavy-duty vehicle classifications. Normal and high-emitting vehicles would be included in the sampling efforts. The overall project implementation will

1. Assemble all available second by-second emission rate data collected from on-road instrumented vehicles tested across the country;
2. Identify vehicle technology, fuel, on-road operating conditions, and environmental variables that are likely to influence vehicle emission rates;
3. Develop a database structure for these and future testing data that can be accessed by interested parties over the Internet;
4. Develop a research plan for collecting on-road emission rate data and associated vehicle/engine operating data from a representative vehicle fleet, controlling for household size, income, other demographic, and geographic parameters;
5. Recruit representative households and vehicles into various sampling programs;
6. Instrument the vehicles with monitoring devices capable of measuring second-by-second emission rates and other important variables in parallel;
7. Perform quality-assurance and quality-control procedures to ensure that data are valid;
8. Over-sample from vehicle technologies or on-road activities that exhibit significant differences in emissions response to on-road operating conditions;
9. Evaluate the variability of collected data and assess when adequate sampling has been performed; and
10. Make the data readily available to all parties interested in model development, enhancement, and validation. Vesting of the EPA in this project and cost sharing should be encouraged.

**Cost:** $15,000,000
**Duration:** 60 months

### 3. Understanding the Emissions Impacts of Surface Freight Transportation

**Problem Statement**
There is a pressing need to develop a better understanding of the relative activity profiles and emissions from the three principal modes of transportation (highway, rail, and water), the interactions among these modes, their impacts on air quality, and methods for reducing those emissions.

The rail industry accounts for 40% of the intercity freight transportation ton-miles, and rail operations consume over 4 billion gallons of diesel fuel per year. Marine vessels use the largest engines in transportation and the dirtiest fuel, with no significant emission regulations or controls. There has been very little research into rail and water emission control technologies and strategies, although emission regulations are now being implemented in the rail industry, and marine regulations are on the horizon. The on-road heavy-duty vehicle fleet has been studied for more than 20 years, but even the state of knowledge for this mode is inadequate. Given that rail and water transportation modes provide better fuel efficiency per ton-mile than highway vehicles, there is a need to understand the air quality impacts of the goods movement system as a whole and the emissions tradeoffs among the various surface transportation modes.

**Proposed Research**
Researchers will

1. Evaluate the status of current emission regulations for each of the modes of transport and where each mode stands in its ability to meet those requirements,
2. Identify improvements in emissions and activity estimation techniques for the three principal surface transportation modes, and
3. Evaluate the emission rates for these modes and recommend changes to those rates if necessary.

The result of this research will include modal comparison for emissions of $NO_x$, $PM_{2.5}$, $PM_{10}$, CO, $CO_2$, $SO_x$, VOCs, and toxic air contaminants. The next task will be to research existing systems and logistics models and recommend improvements to these models if necessary. The researchers shall identify opportunities to reduce emissions through effective modal mix.

Building on existing studies in the highway sector and other relevant modes, the research should evaluate the technology available for rail and marine transport to reduce emissions beyond the current regulatory requirements. This effort will include the testing of fuels, engine modifications, and after-treatment devices that have shown promise, but have not yet been applied to these modes. Testing should include a feasibility and cost-benefit analysis for implementing the technology. Finally, the research shall include evaluation of changes to freight operations that can reduce emissions and result in a recommendation of cost-effective changes to existing operational practices.

**Cost:** $1,500,000
**Duration:** 24 months

## 4. EVALUATING THE SENSITIVITY OF MOBILE6 INPUT VARIABLES AND ADDRESSING UNCERTAINTY IN MODEL USE

**Problem Statement**
The EPA released the final version of the MOBILE6 emissions rate model in January 2002. As the most recent approved version of the model, MOBILE6 will be used in air quality planning in 49 states, for the development of state implementation plans, conformity analyses, and microscale air quality impact assessment. The model provides significant technical improvements over the previous version of the model. Additional laboratory testing data and enhanced statistical analyses serve as the framework for the new emission rate routines embedded within the model programming. Because the model has only recently been released, few sensitivity analyses have been conducted to determine which input variables have the most significant effect on model predictions. It is very important for analysts to ensure that accurate data are provided for most influential variables, because errors and biases in these input values will tend to create the largest output errors. To help avoid the gaming of model results, research on model sensitivity should be

used to develop benchmarking tools to identify reasonable ranges of values for various input variables. Furthermore, guidelines for collecting and evaluating model input data can assist all regional jurisdictions to prepare emissions and air quality modeling.

Many engineering models provide model predictions with 95% confidence intervals. Users can be 95% confident that a single model output value falls between the two bounding values. Confidence intervals indicate the likelihood that the relationship is real and not the result of fitting an equation to random data scatter. When laboratory programs and field experiments provide large numbers of vehicle tests, and when vehicles respond consistently to changes in operating environment, confidence intervals are desirably small. When large confidence intervals are observed around specific modeled relationships, model developers can design new experiments and collect additional data to refine the relationships. Various modeling techniques such as bootstrap and Monte Carlo analysis can be applied to develop confidence intervals around the output of complex models such as MOBILE6.

Taken together, sensitivity and uncertainty analyses can provide a greater understanding of how reliable the outputs from MOBILE6 are likely to be. Given the relatively small data sets used in model development, the typically large vehicle-to-vehicle response noted in testing programs, and the relative uncertainty of model input variables, the confidence intervals for MOBILE6 outputs may be large. Policy analysts would therefore need to help political decision makers understand how to interpret these confidence intervals.

**Proposed Research**

This integrated research project would be undertaken in two parallel efforts. The first research effort would focus on sensitivity analysis, quantifying the effects of changes in input variables on model predictions. The researchers would identify sources of data for all model input variables, assess the real-world distributions of mean input values based on analysis of available data, and quantify the effects that errors in input variables have on predicted MOBILE6 outputs. Analyses should be undertaken for individual variables as well as the combined effect from multiple variables. Analysts would use MOBILE6 scenarios from a number of large and small metropolitan areas to demonstrate the sensitivity effects. The final product would be a guidance document designed to help planners focus data collection resources on the most critical model input variables for each modeling purpose (regional air quality modeling, conformity analysis, and microscale air quality impact assessment).

The second parallel research effort would examine the internal model uncertainty associated with the equations embedded in the MOBILE6 model, including such aspects as baseline emission rates, speed correction factors, temperature correction factors, load correction factors, and high-emitter corrections. The research team would procure the original data used by EPA staff or their contractors to develop each relationship and review the analytical methods employed by the model developers to derive the internal equations. Using bootstrap analysis, Monte Carlo methods, or other appropriate techniques, the researchers would derive the confidence bounds around each internal equation. The research team will use the analytical results to prepare a research plan designed to help the EPA target additional data collection efforts that will tighten the confidence bounds around existing relationships or develop new relationships. Finally, the team would prepare a guidance document designed to help policy analysts and decision makers understand the implications of the refined confidence bounds on policy development.

**Cost:** $450,000

**Duration:** 12 months

## 5. MOTOR VEHICLE CONTRIBUTIONS TO PRIMARY AND SECONDARY AIR TOXICS

**Problem Statement**

Recent studies, including the Multiple Air Toxics Exposure Study (MATES II), have reported that mobile source emissions may be a significant health problem in major travel corridors and may significantly increase cancer risk. Depending on gasoline and diesel fuel specifications, motor vehicles can emit significant quantities of gaseous toxic substances, including benzene and higher (>$C_6$) aromatics, lower carbonyls (formaldehyde, acetaldehyde), 1,3-butadiene, and smaller quantities of longer-chain hydrocarbon species also categorized bythe EPA as mobile source air toxics. Some of the compounds chemically transform or decay relatively quickly in ambient air, whereas others can be long-lived and may form secondary organic aerosols, as fine particulate matter. It is therefore critical to understand, from both air quality planning and environmental justice perspectives, which of these toxic emissions and components have only local impact and which may contribute to regional or "transport" effects.

Because fuel composition differs around the country as a function of local and/or regional regulations and market preferences for additives, the toxic emissions from these fuels may vary from state to state or even city to city. To provide guidance at the local level, it is therefore necessary to accurately characterize the type and distribution of air toxic emissions, by vehicle type, arising from the use of these fuels.

**Proposed Research**

Three research efforts are involved in the overall study.

1. Researchers will assess the relative contribution of on-road and off-road mobile sources to regional air toxic emissions and identify the most significant transportation sources. They will determine the local versus regional nature of these emissions, dispersion rates, and decay and reaction rates of the gases. This would entail a synthesis of currently available literature and a review of existing analytical techniques to estimate mobile source contributions as well as original research. The cost of this effort will run approximately $400,000 and take 18 months to complete.
2. Researchers will measure toxic emissions from highway and other transportation sources (e.g., railroad yards, bus and truck depots, and ports). Monitors will be deployed at multiple locations in up to six urban areas across the United States (each with a different seasonal gasoline and/or diesel fuel specification) for in-situ collection of toxic air contaminant data and facility-oriented emissions during both warm and cold seasons. The product of this phase will be a catalog of toxic species categorized according to fuel properties, vehicle type, facility type, intensity per unit time, and percent local contribution of vehicular emissions to ambient concentration of primary GHG pollutants. The cost of this effort will run approximately $1,750,000 and take 36 months to complete.
3. Researchers will derive emission rates by vehicle type and mode of activity for the most significant toxic pollutant species. They will then disaggregate these rates to characterize both primary emissions and secondary organic aerosols by emission rate, particle size, and factors affecting aerosol formation rates. This effort will apply source characterization data to a set of short-duration average emission rates suitable for use in microscale ambient air quality

simulation models. Based on laboratory analysis, the fate of these primary toxic emissions as secondary organic aerosols at the regional scale will also be quantified for incorporation into air quality models. The cost of this effort will run approximately $500,000 and take 18 months to complete.

**Cost:** $2,650,000
**Duration:** 48 months

### 6. Marine Vessel Emission Rates

**Problem Statement**
Marine vessels are significant contributors to $NO_x$, $SO_x$, and diesel particulate emission in major port cities. Emissions from marine vessels and harbor craft are attracting increased attention for their contribution to air quality problems in port areas, representing one of the largest sources of uncontrolled and unregulated emissions in the United States. The problem is exacerbated by the fact that many of these vessels incorporate the largest transportation engines in the world, which burn the most polluting residual fuel oil available. As more stringent controls are imposed on other sources, the contribution of marine vessel emissions to the overall emissions inventory for a port area by vessel type is becoming increasingly significant.

Current emissions estimates for marine vessels are based primarily on emission factors from engine manufacturers' test stand data or land-based emissions data. There is minimal published emissions data for marine engines during actual operations and no or limited data are available for certain pollutants of concern. The diversity of engine types, fuels used, and operating characteristics means that detailed emission factors are critically important to improve the accuracy of the baseline emissions on which control programs should be based.

**Proposed Research**
This research will compile in-service emission rates reflecting different types of vessels, sizes and types of engines, fuel characteristics, and operating profiles. Emission rates will be compiled for marine vessels by reviewing existing data sources regarding emissions by vessel category, including ocean-going ships, tugs, dredges, ferries, and small commercial boats. Separate rates should be identified by engine type and operating characteristics when appropriate.

Existing emissions data should be obtained from the EPA, the Maritime Administration, state and local agencies, ship engine manufacturers, ship builders, shipping companies, International Maritime Organization, and various international sources. Operating characteristics (including fuel consumption and engine power parameters by activity type) and operating profiles should be obtained from shipping lines, other marine businesses, international organizations, and previous studies.

The program is expected to provide a range of emission rates for $NO_x$, $PM_{2.5}$, $PM_{10}$, CO, $SO_x$, and VOCs, by vessel type, engine size, fuel type (e.g., residual, fuel oil no. 2, other distillates, and compressed natural gas/liquefied natural gas), and operating characteristics (including cruising, maneuvering, and berthing/hoteling operations). Emissions data for toxic air contaminants and greenhouse gases (including $CO_2$, $CH_4$, and $N_2O$) should also be obtained to the extent available. Researchers will compile and make the data available through an Internet database.

Finally, the study should include an evaluation of currently available control technologies for their applicability and effectiveness to reduce emissions, by vessel type.

**Cost:** $250,000
**Duration:** 12 months

## 7. Health Effects of Transportation Emissions

**Problem Statement**
In examining the relationships between transportation and air quality, past emphasis has been placed primarily on the relationship between transportation activities and the magnitude of their emissions, with less attention devoted to the effects these transportation emissions have on exposure levels to different air pollutants for various population groups, and the effects these exposure levels have on human health. Increasing attention, however, is being given to the effects on human health that are associated with transportation investment, operations, and maintenance strategies. An important limitation in establishing the relationship between transportation emissions and human health is that only limited transportation-related health effect studies have been completed. The strengths and limitations of these studies are not widely understood within the transportation community or by public officials. Nevertheless, these results are widely reported in the media and quoted in public debate and sometimes may be misrepresented.

The objective of this research is to better establish and understand the connection between transportation emissions and human health. The scope includes fine and ultrafine particulate matter, air toxics, oxides of nitrogen, and ozone. Fuel issues include current and future low-sulfur and reformulated fuels, as well as alternative fuels. Technologies of interest include conventionally fueled light- and heavy-duty vehicles, and emerging new vehicle technologies. The scope also includes a preliminary assessment of the population groups that are most at risk and the severity of this risk. Population groups should account for demographics, income, residential location (central cities, suburban areas, smaller urban areas, rural areas), and pre-existing medical conditions. Attention also is to be given to differences in exposure levels as a function of location, including in-vehicle, pedestrian, residence, and other building types.

**Proposed Research**
The research should begin with a review and characterization of existing studies that attempt to link transportation and health effects; identifying what is known with reasonable certainty, what is not yet known, important areas of uncertainty, and the degree to which results are transferable across regions. The following questions are of particular concern:

- What is the contribution of particular transportation activities and their associated emissions to observed health effects? Does enough information exist to determine the degree to which transportation sources of emissions contribute to increased risks of particular health effects such as asthma, respiratory disease, cancers, pulmonary disease, and other medical conditions?
- How do transportation-related exposure and health effects vary by pollutant, including both direct and indirect or secondary pollutants? What is the effect of exposure to road dust in

terms of mortality and morbidity risks? For particulate matter, how do health effects vary by particle type and size?

- Are there indirect or compounding effects associated with other risk factors that are important, either by pollutant or by pre-existing medical condition?
- What population groups are most at risk and where are these populations located? How do these effects vary by geographic location, spatial scale, and proximity to a transportation facility?
- What are the levels and durations of pollutant concentrations to which these population groups are exposed?
- How do health impacts vary by type of vehicle, fuel composition, sulfur content, fuel additives, engine technology, and emission control systems, including both existing and emerging approaches? Are there important tradeoffs where the means of controlling one type of vehicle pollutant may increase another form of pollution?
- What data and methods should be used to improve the manner in which health effects are considered in transportation decision making, including both construction of new facilities and the operation and maintenance of existing services?
- Considering risk, health effect, areas of uncertainty, and feasibility, is it possible to identify priorities for the control of transportation sources of pollution?

Researchers should compile the research results into a compendium that can be easily assimilated by transportation professionals and public officials. It is anticipated that this research will be conducted by an interdisciplinary team consisting of public health and transportation professionals.

Based on the results of this research, the researchers should develop a plan for undertaking a major research effort on transportation-related health effects, including the provision for the peer review and analysis of both methods and data.

Sponsorship and research support should be sought from the EPA, National Institutes of Health, and Centers for Disease Control and Prevention.

**Cost:** $750,000
**Duration:** 30 months

## 8. Understanding Emissions and Control Strategies for Off-Road (Nonfreight) Mobile Sources

### Problem Statement

Over the past 20 years, the emissions from every major mobile source category have declined, except for nonroad and off-road sources. Although highway vehicles have been heavily regulated during this period, engines that power construction, agricultural, and lawn and garden equipment; off-road trucks and utility vehicles; recreational vehicles (including all terrain vehicles, snowmobiles, and jet skis); airport ground support; and many other off-road sources remained almost uncontrolled until the late 1990s. The approximately 200,000 pieces of construction equipment operating in New England, for example, account for close to 8 % of $NO_x$ and 25% of the $PM_{10}$ emissions from all sources. Even with the EPA Tier 1 emission standards passed in 1996, and Tier 2 and 3 standards slated for 2006 and 2008, given the long durability

(20–30 years) of these engines, it will be several decades before these vehicles are as clean as heavy-duty highway vehicles.

The EPA's current nonroad emissions model provides CO, VOC, $NO_x$, and $PM_{2.5}$ emissions rates by engine brake-horsepower/hour. However, the emissions data are not well disaggregated by engine or activity, and existing data are scant and poorly understood. As a variety of emission control technologies are evolving, clear procedures to determine the current emissions of these engines are lacking, and it is even more difficult to determine the emissions benefits of these technologies.

**Proposed Research**

This study will evaluate the data sources and emissions estimation methodologies used in the EPA nonroad model. The researchers will investigate and compile off-road source emissions test data from manufacturers, domestic and international agencies, and other sources to provide a better range and breakdown of the variability of emissions by vehicle/equipment type and activity. These data will be compiled and made available through an Internet database.

The researchers will identify the most likely point estimate and a range with confidence intervals for emission factors for CO, VOC, $NO_x$, and $PM_{2.5}$ by vehicle/equipment type and activity. The breakdown of vehicle/equipment types should be disaggregated to the extent the data allow. Emission rates of toxic air contaminants and greenhouse gases (including $CO_2$, $CH_4$, and $N_2O$) should also be collected to the extent available.

In addition, the study should include an evaluation of currently available control technologies for their applicability and effectiveness to reduce emissions, by vehicle/equipment type. Ranges of emission reductions by pollutant should be the primary products of this study element.

**Cost:** $400,000
**Duration:** 18 months

### 9. ESTIMATING MODAL VEHICLE ACTIVITY FOR EMISSIONS MODELING

**Problem Statement**

Considerable resources and effort have been devoted to the development of models that seek to simulate "real world" travel conditions and emissions on a second-by-second basis. These advancements are designed to better account for the deviations from standard driving cycles that produce dramatic increases in emissions. Studies suggest that estimated emission reduction benefits from signal coordination, for example, can more than double when modal activity effects are taken into account.

To use emission rates produced by modal models, it becomes necessary to adapt travel demand models to provide compatible activity data output. Travel demand models currently output traffic volumes and speeds based upon internal volume delay functions. Currently, there is no general method for developing appropriate speed and acceleration data from these aggregate model outputs. Lookup tables established using small area simulation approaches are not well suited for evaluating a number of transportation control measure strategies (ramp metering and related intelligent transportation system measures), because they are based on volume-to-capacity ratio and basic link characteristics.

Simulation models used in corridor and microscale analyses must be similarly adapted to link with modal emissions models. Directly linking to a microscopic simulation model does not currently appear advisable, given the evidence in the literature that current microsimulation models may fail to produce realistic acceleration and deceleration behavior. Many simulation models contain no provision for less than “emergency braking,” and car-following algorithms may not be accurate. There is a need to assess the algorithms used in standard practice simulation models for compatibility with modal emissions models.

Research is needed to fill critical data gaps, and validate and enhance the body of knowledge with respect to speed post-processing techniques, mesoscopic regression models that predict the number of stops along arterials, and simulation in small scale networks to generate link level modal activity.

**Proposed Research**

This research will identify promising analytical techniques, likely post-processing, that will enable typical four-step planning models, used to produce region-wide estimates of vehicle activity data, to interface with modal emission rate models. The research will also establish guidance on determining an appropriate link classification system based on the degree of variation in the characteristics of different highway facilities and the quality of travel demand model inputs. Because the accuracy of such approaches depends on the accuracy of the estimated traffic volumes and speeds, sensitivity analysis and reasonableness checks will be needed to verify the accuracy of modal activity estimates. Data collection, field observation, and small area simulation may be needed to establish speed/acceleration conditions for signalized intersections that account for slowdowns and delays that do not involve complete stops. The research will identify and implement additional experiments to generate vehicle activity data and develop relationships between traffic conditions (volume/capacity), link characteristics, and control/management scenarios.

On the microscale and corridor simulation side, the researchers will evaluate the accuracy of outputs from current simulation models with respect to speed and acceleration profiles. Based on the results, the researchers will propose modifications to the simulation models that will enhance their use in modal emissions modeling. Targeted research and validation efforts will be needed to refine the modal activity estimates.

**Cost:** $500,000
**Duration:** 24 months

**10. HIGH-EMITTER CHARACTERIZATION**

**Problem Statement**

A small fraction of light-duty vehicles on the roadway is responsible for a large fraction of fleet emissions. These "high emitters" (typically malfunctioning and tampered vehicles) exhibit high emissions rates under many operating conditions. Real-time measurements using open path Fourier Transform Infrared Spectroscopy in the aerodynamic wake flow of moving vehicles undergoing deceleration, acceleration, and cruise have shown that high emitters are outliers in the normal vehicle population and distort the average emission rates of the vehicle fleet. High emitters are usually defined with respect to the emissions of other vehicles within a technology group (model year and emission control technology groups that behave similarly with respect to emissions production). Thus, when a new vehicle and an old vehicle both exhibit a large gram/mile emissions rate, the new vehicle might be considered a high emitter, whereas the older vehicle might be considered a normal emitter. The literature provides a wide range of estimated emission inventory contributions from high emitters (e.g., 10% of the vehicles are responsible for 50% of the emissions, or 20% of the vehicles are responsible for 50% of the emissions). The differences in contribution estimates stem from differences in "high-emitter" definitions and methods used to estimate the activity and emissions rates for these vehicle groups. Clear high-emitter definitions are needed. More precise methods for identifying high emitters (both spatially and temporally) and quantifying their emissions will improve emissions modeling and provide a basis for evaluating emission control strategies that target these vehicles.

**Proposed Research**
Researchers will conduct a literature review on light-duty vehicles high-emitter definitions for CO, HC, and $NO_x$, and evaluate the previous studies to ensure that technology group definitions represent groups of vehicles that behave similarly in terms of emissions production and their response to different operating conditions. Based on the literature review and analysis of existing data, researchers will identify cutpoints by pollutant (in grams/mile or grams/second) to define high-emitting vehicles for various technology groups. The researchers will develop means (either through remote sensing networks, IM240 or other IM program test results, and/or actual on-road in-use testing) to identify the emitter characteristics of vehicles on urban roadways. Using these techniques, the researchers will then identify the fraction of high-emitting vehicles for each technology group and activity for use with the MOBILE model. The research will yield basic methods to apply on-road technology group fractions and emitter distributions within the context of four-step travel demand modeling and High Performance Monitoring System modeling frameworks so that local subfleet information can be used in the MOBILE6 emissions modeling process. These techniques will be tested in three urban areas that exhibit diverse geographic, socioeconomic, aggregate fleet, and inspection and maintenance program characteristics. The team will analyze the spatial and temporal distributions of high-emitting vehicle operation as a function of vehicle registration and socioeconomic parameters. In addition to analyzing high-emitter activity by technology group, the team will also analyze the overall impacts of the highest emitting vehicles in the fleet and assess the potential effectiveness of high-emitter control strategies. Analyses may include

1. I/M repair policy changes and other I/M improvements,
2. Implementation of focused vehicle scrappage programs,
3. Manufacturer recall for specific failures, and
4. Emissions-based annual vehicle registration fee programs. All analyses should include an overview discussion on equity impacts based on high-emitter ownership and socioeconomic correlations.

**Cost:** $300,000
**Duration:** 24 months

**Immediate Transportation and Air Quality Research (Short Term)**
As a result of the research needs conference, the transportation and air quality research needs work group identified 10 research projects that must be accomplished over the next 5 years.

However, the work group also identified six critically important and relatively inexpensive projects with immediate pressing needs. These projects must be accomplished in the near term and cannot wait for the standard 1- to 3-year research approval and implementation process. The work group believes that consulting firms could quickly accomplish these six projects for less than $100,000 per project. These projects are vital to transportation professionals, improving analytical tools and enabling transportation professionals to provide useful input into upcoming regulatory developments. The six projects are as follows:

### 11. Ambient Air Quality Monitors and Data Used in Air Quality Designation

**Problem Statement**

With the likely designation of many new ozone nonattainment areas under EPA's 8-hour ozone standard, it is imperative that an adequate number of monitors be in place, that monitor sites meet EPA requirements, and that data used to determine nonattainment designations be quality controlled and credible.

**Proposed Research**

Researchers will conduct a field review of monitor locations and monitored data in a number of areas at risk of being newly designated nonattainment under the 8-hour ozone standard. The researchers will ensure that the monitors have been appropriately sited and maintained in accordance with EPA requirements, that the data are properly quality control checked, and that the data are appropriate for making air quality designations.

### 12. PART5/MOBILE6

**Problem Statement**

The PART5 model provides emission rate estimates for primary emitted particulates, brake and tire wear emissions, and re-entrained road dust. Given the high degree of uncertainty in the PART5 model, its use has not been mandated in regulatory applications. EPA is in the process of integrating PART5 into MOBILE6. Given that MOBILE6 is the latest approved EPA model, once PART5 has been integrated, it might be argued that MOBILE6 must be used in regulatory decision making with respect to particulate matter. For example, could the EPA mandate the use of MOBILE6 for microscale PM modeling? Given that the model has only recently been integrated into MOBILE6, and has not been improved, it does not seem reasonable to change the status of the model with respect to use in regulatory and planning procedures.

**Proposed Research**

This research effort will examine the policy implications that result from the integration of the PART5 model into MOBILE6. Various options for use of PART5 will be assessed and the policy implications of these options will be summarized. This information will help transportation professionals provide input to EPA on the use of PART5 prior to any regulations or guidance being issued on its use.

### 13. Helping Rural Areas Demonstrate Conformity

**Problem Statement**

EPA's designation of 8-hour ozone and $PM_{2.5}$ nonattainment areas in the 2004–2005 time frame will significantly increase the number of rural areas subject to conformity requirements. Rural nonattainment and maintenance areas in many states will be designated for the first time and will face unique challenges in demonstrating transportation/air quality conformity. Most rural areas do not have a comprehensive planning process to identify and address long-term growth issues or a local authority, such as an MPO, to determine conformity. Even with a 1-year grace period to demonstrate conformity, newly designated rural areas will still face major obstacles in carrying out the required political, institutional, and planning activities in a timely way to comply with the conformity rule.

**Proposed Research**
The research will build on FHWA's survey of rural areas and will address both ozone and PM standards. The researchers will implement a survey of rural areas likely to be newly designated as nonattainment areas, adjacent nonattainment areas currently participating in the conformity process, and the associated state agencies. The survey will be designed to assess the political, institutional, consultative, planning, analytical, and data issues likely to arise when conformity becomes applicable in these rural areas. The researchers will combine the results of these surveys with interviews of other conformity stakeholders to:

1. Identify problems that rural areas are currently encountering, or expecting to encounter, in demonstrating conformity;
2. Identify approaches being used, or planned, for addressing the problems; and
3. Identify further studies and research required to address the problems that are not being adequately addressed.

The research will also assess the need for updating state implementation plans in rural areas and whether the choice of conformity tests provided in the 1997 conformity rule amendments has helped rural areas. This effort will also include an examination of alternative ways to comply with the conformity rule.

## 14. DECREASING EMISSIONS FROM LOCOMOTIVE ENGINE IDLING

**Problem Statement**
The standard operation of locomotives involves extensive periods of idling, resulting in significant emissions and energy consumption. New technologies can provide more efficient idling or eliminate the need for idling, thereby decreasing emissions and reducing fuel consumption. More broadly applied, these technologies could achieve greater emission reductions and energy savings.

**Proposed Research**
The researchers will evaluate the emission reduction and energy conservation benefits of new technologies, including auxiliary power units and hot start devices. The costs and benefits of each technology will be assessed for various locomotive operating scenarios. The researchers will also assess the extent of market penetration and the current availability of each technology. Policies and incentives designed to increase the application of such technologies throughout the

railroad industry will be assessed. A report summarizing these findings will be disseminated throughout the rail industry and to appropriate regulatory agencies.

## 15. Improving VIN Decoder Software

**Problem Statement**
Many users of EPA's MOBILE model are developing regional or local fleet characterization data to more accurately predict mobile source emissions. Vehicle identification number (VIN) decoder software is often used to process registration data or observed fleet data to characterize on-road vehicle classes and age distributions. Limitations in VIN decoder software affect the accuracy of these predicted fleet distributions.

Recent research on two different vehicle data sets identified VIN decoder errors for several vehicle characteristics. These errors could result in a bias toward newer vehicles and an underestimation of mobile source emissions.

**Proposed Research**
The proposed research will build upon recent VIN decoder work to:

1. Summarize the important vehicle and engine technology variables that have been used in advanced emission rate models or may be used in future models,
2. Identify all commercially available VIN decoders, and
3. Procure and evaluate the ability of these VIN decoders to produce accurate fleet characterization data for use with current and advanced models. Based on this evaluation, the researchers will scope out a research plan and budget to develop a public domain VIN decoder software.

## 16. Diesel Emissions Reduction Programs Data Repository

**Problem Statement**
In recent years, diesel retrofit and other diesel emission reduction programs have been initiated in various locations throughout the country. The primary purpose of these programs is to achieve diesel emission reductions on an accelerated basis from existing diesel-fueled vehicles, heavy-duty diesel trucks, and construction equipment in particular. Such reductions are occurring in advance of the phase-in of EPA’s heavy-duty engine and low-sulfur fuel rules. A centralized database of information on the costs and effectiveness of various heavy-duty diesel control strategies would provide significant efficiency benefits to areas implementing such programs.

**Proposed Research**
The researchers will prepare a central repository database that can be accessed over the Internet providing information on each of the diesel retrofit and control programs implemented to date. The records for each program must include:

- Location of program,
- Nonattainment status of the area,
- Name of implementing agency,

- Program components (e.g., retrofits, engine changeouts, fuel parameters, construction of fueling infrastructure, etc.),
- Incentives offered,
- Voluntary versus mandatory basis,
- Estimated program cost-effectiveness (dollars/year per ton/year),
- Criteria for participation in programs,
- Program funding sources and amounts, and
- Quantification of emission reductions and "credit" for reductions (e.g., state implementation plans vs. conformity credits).

**Collaborative Research Needs Statements**

### 17. Emissions and Fuel Economy Testing of Hybrid Electric Vehicles (HEVs) to Specify a New Mobile Class

For full text, see Statement 11 under Energy and Sustainable Fuels

### 18. To What Extent Do Motor Vehicles Affect Asthma and Respiratory Health?

For full text, see Statement 10 under Community Impacts, Environmental Justice, and Public Involvement

# Community Impacts, Environmental Justice, and Public Involvement

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RESOURCE PAPER

# Community Impacts, Environmental Justice, and Public Involvement

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The legal basis for the term "environmental justice" is found in Title VI of the Civil Rights Act of 1964, Title VIII of the Civil Rights Act of 1968, the National Environmental Policy Act of 1969 (NEPA), and the Federal-Aid Highway Act of 1970 (23 USC 109(h)). The legal basis for the terms "community impact assessment" and "public involvement" can also be found in the Federal-Aid Highway Act of 1970 (23 USC 109(h)) and NEPA. Achieving environmental justice, assessment of community impacts, and public involvement in relation to transportation activities funded by the federal government collectively is a requirement of Executive Order 12898, the U.S. Department of Transportation (U.S. DOT) Order on Environmental Justice, and the FHWA's Order to Address Environmental Justice.

The term environmental justice is inclusive of issues that surround transportation equity, community impacts, accessibility, disproportionate impacts, and mitigation of those impacts. Community impacts or impact assessments includes such issues as community profiling, meaningful community involvement, education/training, consensus building, decision making, and implementation. Public involvement is considered a process of two-way communication between citizens of the community and the local, state, and federal governments.

Although community impacts, environmental justice, and public involvement are separate and unique terms and processes, they have several similarities. This paper will explore those differences and similarities and offer for consideration some suggestions from a research standpoint on how they should proceed, both separately and in conjunction with one another.

The term environmental justice has been difficult for many professionals in the transportation field to define; however, nationally it has become a widely used term. Many feel the need to link the term with Title VI of the Civil Rights Act of 1964. Precedent setting legal cases through the 1970s and 1980s surrounding environmental justice have been found in land-use type cases (i.e., those involving hazardous waste sites, landfills, zoning, etc.). In *Final Guidance for Incorporating Environmental Justice Concerns in EPA's NEPA Compliance Analyses*, the Environmental Protection Agency (EPA) defines environmental justice as follows:

> The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal,

> and commercial operations or the execution of federal, state, local, and tribal programs and policies. (*1*)

EPA's definition therefore is much broader, including "meaningful involvement and also regardless of income," than what is required by law in the Civil Rights Act (Title VI, § 601, P.L. 88-352), which states "that no person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be otherwise subject to discrimination under any program or activity receiving Federal financial assistance.

In FHWA's 1996 *Community Impact Assessment: A Quick Reference for Transportation*, community is defined

> in part by behavior patterns which individuals or groups of individuals hold in common. These behavior patterns are expressed through daily social interactions, the use of local facilities, participation in local organizations, and involvement in activities that satisfy the population's economic and social needs. A community is also defined by shared perceptions or attitudes, typically expressed through individuals' identification with, commitment to, and attitude toward a particular identifiable area. In addition, there are other concepts of community, which are not based on spatial relationships. Communities may be based on a common characteristic or interest, such as religion, ethnicity, income strata, or concern for the economic viability or a region, which provides a psychological unity among members. (*2*)

In the 1994 *FHWA/FTA Interim Policy on Public Involvement and Questions and Answers,* the FHWA and FTA define the public to include

> citizens, affected public agencies, representatives of transportation agency employees, other affected employee representatives, private providers of transportation and other interested parties (e.g., 23 USC 134(h)). The FHWA and FTA define the public broadly as including all individuals or groups who are potentially affected by transportation decisions. This includes anyone who resides in, has interest in, or does business in a given area, which may be affected by transportation decisions. The public includes both individuals and organized groups. In addition, it is important to provide similar opportunities for the participation of all private and public providers of transportation services, including, but not limited to, the trucking and rail freight industries, rail passenger industry, taxi cab operators, and all conventional and unconventional transit service operators. Finally, those persons traditionally underserved by existing transportation systems such as low income or minority households and the elderly should be explicitly encouraged to participate in the public involvement process. (*3*)

The meaningful involvement of the public is clearly the link between community impacts, environmental justice, and public involvement processes. How we involve the public, how we define their communities, and how we treat them in a fair and equitable (nondiscriminatory) manner is the key to ensuring that each of the above terms in relation to transportation needs and solutions are addressed properly both individually and collectively and in the spirit of existing laws, regulations, and guidance. This is a refocus of the past, and several factors have contributed to this change.

Since the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), there has been a federally mandated emphasis on early, proactive, and sustained citizen input into transportation decision making, with special outreach efforts targeted at traditionally underserved populations. The passage of the Transportation Equity Act for the 21st Century (TEA-21) has also reinforced this change. In 1994, President Clinton signed Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, requiring that each federal agency make environmental justice part of its mission. This executive order mandates that "each Federal agency identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations (*4*). In 1997, the secretary of transportation signed the U.S. DOT order on environmental justice, *Department of Transportation Order to Address Environmental Justice in Minority Populations and Low-Income Populations.* The U.S. DOT is required to continuously monitor its programs, policies, and activities to ensure that disproportionately high and adverse effects on minority and low-income populations are avoided, minimized, or mitigated. The U.S. DOT's order states that procedures need to be established to "provide meaningful opportunities for public involvement by members of minority populations and low-income populations during the planning and development of programs, policies, and activities" (*5*). Additionally, the order states that the U.S. DOT will "collect data and conduct research associated with environmental justice concerns" (*5*). In 1998, the FHWA issued its order on environmental justice, *FHWA Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*.

The passage of these two highway bills, the signing of Executive Order 12898, the U.S. DOT order, and the FHWA order, and their contents was derived from a growing need by the public, communities, and the traditionally underserved to ensure that the power no longer rests with the government alone, and that all individuals and groups have a voice prior to and leading up to the final transportation decisions that affect them, their communities, and the greater surrounding regions.

Additionally, there were two executive orders released in 2000 that directly or indirectly impact the achievement of environmental justice and transportation decision-making processes. Executive Order 13166, *Improving Access to Services for Persons with Limited English Proficiency (LEP)*, was signed by the President Clinton on August 11, 2000, and specifically requires that each federal agency "examine the services it provides and develop and implement a system where LEP persons can meaningfully access these services" (*6*). Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*, was signed by the President Clinton on November 6, 2000. This executive order requires that agencies follow certain criteria when formulating and implementing policies that have tribal implications. Specifically, the order requires that each agency have an "accountable process to ensure meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications" (*7*).

## THE FUTURE

It has become evident that since the passage of ISTEA there has been a much greater interest in involving the public effectively; ensuring that communities are properly defined and that impacts to them are assessed, and specifically that minority and low-income populations are not left out of this more engaged public involvement and community impact assessment. Defining the community, how they are involved in transportation decision making, and ensuring that minority and low-income populations are proactively engaged in these processes should be a goal of transportation professionals.

In the past, transportation professionals, organizations, and institutions have been challenged through legal venues regarding public involvement and environmental justice. These legal venues have included the NEPA, the Federal-Aid Highway Act of 1970, and Title VI of the Civil Rights Act of 1964, with the results that transportation programs and projects are prevented from moving forward in a timely manner and adding significantly to the ultimate costs. Because community impacts, environmental justice, and public involvement have a considerable overlap, it should be in the interest of transportation professionals to proceed in a streamlined fashion. Over the past 5 years many such professionals have embraced the process of community impact assessment to the point where they feel that if it is done properly than environmental justice and public involvement will be automatically addressed. One could also argue that a well-implemented public involvement program, both at the system level and project level, if done properly, would address environmental justice and community impact assessment. A well-thought-out-public involvement program will include public ownership of policies/sustainable and supportable decisions, decisions that reflect community values, efficient implementation of transportation decisions that reflect citizen and community involvement, and enhanced agency credibility. Research is needed in this area to determine how future guidance, policies, and regulations should be formulated and structured to ensure that existing laws are being followed, and that duplicative efforts are not adding unnecessary time and costs to the overall delivery of a transportation program and/or project.

Over the past 5 years, environmental justice and Title VI have brought about significant advancements, challenges, and controversy within the transportation sector. A 2001 U.S. Supreme Court decision in the Sandoval case, which concerned a private citizen's right to sue under Title VI, and the decision by the U.S. Appeals Court in the Camden case subsequent to the Sandoval case, however, has set back grass roots efforts in the environmental justice circles. Many transportation professionals are currently challenging how these cases will be challenged in the future. Although the Sandoval case has blocked private citizens from bringing a disparate impact case under the Civil Rights Act, it did not stop citizens from bringing such "intentional" discriminatory cases or absolve the federal government from ensuring under their programs that disparate impact, which rises to the level of intentional discrimination, occurs. Therefore, the question remains, will transportation officials see more or less of an advancement when addressing environmental justice under the federal government's programs, bills, regulations, policies, and guidance?

Some professionals argue that enough still has not been done at both the systems level and the project level to ensure that environmental justice is addressed and that the traditionally underserved public is properly involved in the decision-making process. Will the federal government determine where the benefits and burdens are being distributed within their federal-aid programs? What types of mitigation will professionals undertake in their transportation programs and projects to ensure fair and equal treatment of all people?

**New Partnerships**

The key to establishing the link between community impacts, environmental justice, and public involvement is through forming a new partnership. Webster's dictionary provides the following three definitions of partnership: (1) the state of being a partner, participation; (2) the relationship of partners, joint interest, association; and (3) an association of two or more people who contribute money or property to carry on a joint business and who share profits or losses in certain proportion. Forming partnerships moves agencies from the "us and them" mentality to "us." There are many reasons why forming partnerships to address environmental justice, community impacts, and public involvement makes sense. There are many more players in the decision-making process to address the complexities of transportation technology and financing. Coupled with these complexities there are even more challenges with multi-jurisdictional boundaries. The challenges arise because one jurisdiction or perhaps even one metropolitan area by themselves can no longer develop and implement the transportation plans. Solving our transportation problems in the future will require the involvement of multimodal planning and cross-jurisdictional involvement. As these partnerships continue to form to address complex transportation problems, involvement of the public and assessment of the impacts to our communities will ultimately determine how successful transportation planning and implementation moves forward.

**Policy Development**

Attention needs to be given to future policy development and how new policy affects overall transportation decisions and outcomes. Streamlining the processes and ensuring that duplication and overlap do not occur will be the transportation professional's challenges of the future. No longer is the time or money available for municipalities, metropolitan planning organizations, state DOTs, and the federal government to set policy that is inconsistent with the overall transportation vision for a region, state, or nation. Future policies need to ensure a continuous process from statewide planning, to corridor planning, to area planning, to programming, to project development, through project implementation.

**Performance Measures**

Assessment of our efforts with community impacts, environmental justice, and public involvement must not be ignored. In the future, measures of effectiveness in assessing community impacts, the distributions of benefits and burdens, and how we involve the public will guide our efforts. An outcome-based evaluation could be the key to performance measurement discussed in ISTEA. These performance measures should review how well the expectations of participants were met, costs in relation to benefits, and effects on decision making. An outcome-based evaluation would help guide how community impact assessment, environmental justice analysis, and public involvement is transformed in the future.

**New Technologies**

Technology will play a vital role in addressing community impact assessment, environmental justice analysis, and public involvement. In addition to transportation issues, the public is often involved in issues such as security, healthcare, public school funding, and infrastructure. . The use of innovative new technologies such as video conferencing and simulation, kiosks, on-line services, and CD-ROM presentations is a way to streamline efforts both internal to public agencies as well as to our external client.

**Structured Decision Processes**

With recent emphasis from the public, businesses, and Congress on "Environmental Streamlining," it is argued that the value added, both in time and cost savings, should be examined with those state DOTs that have embraced community impact assessment, environmental justice, and refocused their public involvement to include the traditionally underserved. Is value being added by just addressing community impacts or is it a combination of community impact assessment, environmental justice analysis, and public involvement? Also, it is not disputed that all three topics should be engaged and started early in the process, long before the planning begins. It is important to determine how many of these states are actually proceeding in this manner and how has it positively affected their transportation programs?

To deal with the tough issues and complexities of transportation issues in the future the structure of our decision process will have to change. We need to start with defined goals from an overall vision of what a transportation system should be at the state, regional, national, and global levels. Decisions then need to be linked to the goals and efforts of reaching consensus among our stakeholders. Such approaches need to be used in public involvement, community impact assessment, and environmental justice analysis. Quantifiable criteria can then be used to evaluate which alternatives meet the desired goals/outcomes. These results can encourage constructive inclusive decisions that include stakeholders in the process.

**Outreach Efforts to the Traditionally Underserved**

Our society as a whole will not benefit if we leave the less fortunate and traditionally underserved behind. The Minnesota DOT has embraced community impact assessment and environmental justice by developing an overall vision for their DOT; *Hear Every Voice.* The Minnesota DOT defines the traditionally underserved as people of color, low-income constituencies, community and neighborhood groups, and civic and cultural groups (*8*). Minnesota's impetus for developing a project targeted specifically at the traditionally underserved was the intent of the legislation for ISTEA. The project, *Non-Traditional Transportation Stakeholder/Dialogue Project,* was developed to learn what the elements of successful outreach efforts to nontraditional stakeholder groups should include (*8*). Two very important findings of the project were better access to transportation planning and design processes andimproved opportunities for meaningful involvement by nontraditional stakeholders. What the Minnesota DOT found through this project, that many other DOTs are beginning to realize, is that traditional approaches and techniques for involving the public in transportation decision making would not work. New methods and technologies need to be developed and implemented to reach the traditionally underserved.

From a research standpoint, our efforts in the future need to include the following in community impact assessment, environmental justice, and public involvement:

- New partnerships,
- Policy development,
- Performance measures,
- New technologies,
- Structured decision processes, and
- Outreach efforts to the traditionally underserved.

## REFERENCES

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6. Executive Order 13166. "Improving Access to Services for Persons with Limited English Proficiency (LEP)." *Federal Register,* Vol. 65, No. 159, August 16, 2000, pp. 50119–50122.
7. Executive Order 13175. "Consultation and Coordination with Indian Tribal Governments." *Federal Register,* Vol. 65, No. 218, November 9, 2000, pp. 67249–67252.
8. *Non-Traditional Transportation Stakeholder/Dialogue Project Final Report.* Minnesota Department of Transportation, St. Paul, April 1997.

RESEARCH NEEDS STATEMENTS

# Community Impacts, Environmental Justice, and Public Involvement

### 1. The Impact of the Transportation System on the Safety of Minority Populations

**Problem Statement**
Currently, it is very difficult to determine the overall and cumulative safety impacts of the transportation system on minority populations. This is partly due to the variety of environments, vehicles, and measures of injury across modes.

Better cumulative impact measures would contribute to better National Environmental Policy Act (NEPA) analyses, assist in transportation planning, and contribute to equity and fairness in environmental initiatives.

Some minority populations have different transportation circumstances than some nonminority populations. For example, African–Americans owns cars at a lower rate than other populations. Greater use of buses may contribute to health, but walking along roads without sidewalks may lead to greater incidence of injuries from vehicles. In addition, cars that low-income people own may be older than those owned by higher income people. Also, older cars have fewer safety features than newer cars. What effects do these different circumstances have on the safety of minorities? How can safety impacts be measured and compared across modes?

**Proposed Research**
Develop common measures of safety impacts of the use of transportation modes, vehicles, and facilities on minority populations and use these measures to determine differential impacts on minority populations compared to nonminority populations. Disaggregate the data by racial/ethnic group to help provide transportation planning practitioners with knowledge and data that will help them focus on where additional safety efforts for the transportation system are necessary. These measures would also provide a model for evaluating health measures in transportation.

**Cost:** $200,000
**Duration:** 12 months

### 2. Methods for Determining Population Characteristics in Rural Areas for Community Impact Assessments and Improved Public Involvement

**Problem Statement**
Part of the conundrum of “rural development” is that rural communities in many states are experiencing new population and development patterns, which require new transportation services and facilities. However, the population and demographic information needed for planning and structuring such a project is usually outdated or inadequate. How can we better identify “community” interests in low-density areas, particularly where there are cultural barriers such as multiple languages or ethnic groups who do not interact with others?

The most widely accepted and used source of information on income levels for environmental justice analysis is the U.S. Census Bureau. However, such analysis based on income levels is sensitive, difficult to measure, and problematic to assess. Due in part to the sensitivity of income-based data, census income results are narrowed only to the block group level. Block groups vary in size, and in rural areas are arbitrarily determined by geographical features. For such areas, this block group level of detail is often of little use in capturing an accurate picture of the economic variability that exists within a transportation project's area of potential environmental or community impact. Furthermore, the variability in data from block group to block group proves to be problematic and inaccurate during comparisons and assessments of potential impacts.

Although this problem is not as acute for other census data, there is a similar lack of available information for communities where the population shifts may be more rapid.

Alternative sources of economic and demographic information and methods for interpreting existing data need to be identified or developed for rural areas. The results of this research will improve the accuracy, reliability, and sensitivity of environmental justice and community population analysis in rural areas and should result in a reduction in the time required to identify appropriate transportation projects for these communities.

This information and analysis approach can also prove useful to tribal communities and other underserved populations that are seeking to improve the results of their community visioning and public involvement strategies.

**Proposed Research**

The research should identify existing sources of economic and demographic data for rural communities and should suggest methods to document or predict changes in population composition. At a minimum, the data should be able to be stratified by typology of rural and/or exurban community economies (e.g., old/declining, insulated, mature/stable, and new/developing). Methods to identify the different rates of change in different communities should be included.

One goal is to understand the dynamics involved in the process of communication among diverse and underserved populations, including organizational cultures, to achieve community visioning and public involvement. The research would take an integrated approach to data research, collection, analysis, and the creation of public policy that keeps communities whole while preserving their sense of identity and culture. The research should also identify methods of characterizing rural populations.

The results of the research will provide a variety of analytical methods that can be used to help ensure success in reducing barriers to cooperation for transportation in rural communities. The product should be translatable into formats that can be used by communities where English is not the primary communication language.

**Cost:** $250,000
**Duration:** 2 years

### 3. Assessing the Impact of New Transportation Investments and Emerging Transportation Technologies on Traditionally Underserved Groups

**Problem Statement**

Transportation investments produce different benefits for different members of the public. Decision makers often need to know how these benefits may be distributed, especially on traditionally underserved social groups.

Compared to prior studies that focus on the measurement of direct outputs of transportation improvements such as more lane miles, however, the measurement of benefits (or outcomes) realized by different social groups is complex. Prior studies often measure benefits as a function of *outputs* from agency activities rather than *outcomes* that are the social and economic changes resulting from service provision. Perhaps this is one reason why the social benefits of different forms of transportation investments are so frequently overlooked. Complicating the picture are emerging transportation technologies and their potential to benefit social groups differently.

The difference in distribution and the level of benefits in part is based on different choices in location and travel behavior. It is well known that, within regions, households make location choices as a function of preferences and economic constraints. This process produces "sorting," or geographic clustering of similar types of households into neighborhoods on the basis of social and economic characteristics. Because transportation benefits are distributed geographically and influence household location patterns based on their social and economic class, the examination of the spatial patterns of benefits associated with new transportation investments, and emerging transportation technologies, has implications for traditionally under-served social groups.

**Proposed Research**

This research will be undertaken in three phases. The first phase will be a literature search and review of current research focusing on identifying those theories and associated methodologies that may be adapted to assess the impact of new transportation investments and emerging transportation technologies on traditionally under-served groups. The second phase will operationalize those methodologies in ways that may be used to address key issues relating to the proposed research. The third phase will apply those methodologies to a pilot study to test their ability to generate results that are useful to decision makers concerned about how traditionally underserved social groups may benefit from new transportation investments and emerging transportation technologies.

**Cost:** $450,000
**Duration:** 30 months

### 4. Economic Viability and Community Impact Assessments in Transportation Decision Making

**Problem Statement**

Transportation decision makers and stakeholders have touted the economic development benefit of improvements to our transportation infrastructure. It is important to understand transportation environmental justice and equity, and balance the incidence of impacts in decision making. One familiar axiom is that four-lane roadways are directly tied to economic development. In many state highway departments it is widely accepted that any roadway expansion project will spur economic development and provide jobs. However, there are no hard data to demonstrate under what situations roadway expansion will provide economic development opportunities. In rural areas where four lanes are not needed for capacity, it has not been documented that roadway expansion draws industry and provides jobs. Unfortunately, these project decisions are often not made in the context of the overall community impacts. It may not always be in the best interest of the community to sacrifice wider sidewalks, bikeways, on-street parking, and other nonvehicular elements to provide extra roadway travel lanes on low-volume roadways.

The community impacts, including the effects of business relocations, are particularly important elements to evaluate in the decision to widen a roadway. Many businesses that have developed next to the roadway are dependent on the traffic and their specific location. Traditionally, business impacts are handled under the *Uniform Relocation and Real Property Acquisition Act*. Impacts are mitigated primarily from a real estate value perspective. This ignores the importance of individual businesses to the fabric of the community. Business losses can even result in reductions in overall property values in the neighborhood and/or community. These factors and impacts are often unknown without a detailed community impact assessment (CIA).

**Proposed Research**

The research will involve a review of projects where economic development has been the primary, stated project purpose and need of a proposed roadway expansion project. Roadways are often expanded to four lanes, where projected capacity warrants only two lanes. Use of existing case studies and available research will demonstrate if economic development and jobs result from roadway expansion. This research must include assessing the resulting community impacts. On balance, were impacts such as community cohesion, visual resources, pedestrian facilities, and bicycle accommodation as important as roadway expansion in decision making? Without a good community profile, by means of a CIA, the real economic vitality, benefits, and impacts cannot be assessed. Standard models provide little information on CIAs or social and economic differences. Also, the researcher must consider the impacts on different social and economic communities to examine the equitable distribution of the costs and benefits of project development.

The research should focus particularly on the effect of business impacts and their relocation on communities. Often small businesses along the roadway play a large role in the community. Factors of decision making can extend well beyond the economic benefits provided. A new business at a new location may or may not provide a few extra jobs. How can this be predicted? Also, what is the real cost to the community from the loss of business at a particular location? Perhaps a wider sidewalk, rather than an extra travel lane, is a better economic enhancement. The researcher must appreciate definitions of social equity and environmental justice and develop processes for evaluation of impacts and their distribution. Research is needed to understand the community dynamics and interplay with economic development for state highway departments and other decision makers to best serve the public interest in roadway expansion projects.

**Cost:** $150,000
**Duration:** 16 months

**5. EFFECTIVE DIALOGUE WITH COMMUNITIES OF DIVERSE BACKGROUNDS ON COMPLEX TRANSPORTATION ISSUES AND DECISION-MAKING PROCESSES**

**Problem Statement**
Transportation has been identified as one of the issues of greatest citizen concern in surveys of communities across the country, yet there is a broad divergence in opinion concerning the causes of, and solutions for, transportation problems. On the whole, issues are addressed on a project-by-project basis rather than in a holistic community context. The issues are complex and cannot be understood through typical sound-bite information. More in-depth citizen education on transportation issues, including understanding of decision-making processes, is needed to facilitate a dialogue with communities, thereby leading to more consensus-based decision making. Citizens often adopt the view that "everything has already been decided," because they don't know who decides what and when. This education is challenging, and is often not performed or is done inadequately.

This education process is complicated by the increasing cultural diversity within communities. The lack of cultural sensitivity by transportation professionals leads to a feeling of community disempowerment and a "disconnect" between community values and transportation decisions. Because of demographic changes, we need better information on how to interact with these populations and other underrepresented groups in transportation decision making.

**Proposed Research**
The research should be conducted in two phases. The first will identify innovative approaches for community education and dialogue that have been implemented effectively in other arenas that could be used by DOTs, metropolitan planning organizations (MPOs), cities, and counties. Second, techniques for effective engagement of diverse communities (e.g., religious groups, non-English speaking groups, the elderly, the disabled, and low-income and minority groups) should be identified and presented in case studies to ensure successful dialogue.

Phase II should explore institutional barriers to implementation of these successful approaches and recommend methods for removing them.

**Cost:** $250,000
**Duration:** 18 months

### 6. ESTABLISHING EQUITY MEASURES FOR ENVIRONMENTAL JUSTICE COST-BENEFIT ANALYSES

**Problem Statement**
There are many definitions of the term "equity." The way equity is defined influences the distributive goals of an action. Cost-benefit analysis, for example, usually employs the utilitarian concept of equity: the distribution of goods and/or services that maximizes total welfare or social utility. The alternative with the highest net benefit is the "winner." However, this approach does not address the distributions of benefits or burdens on specific populations because it does not consider individual or community factors. An alternative with the highest net benefit could concentrate benefits in one population segment and burdens in another. Such an outcome may lead to potential environmental justice problems. Thus, it is important to understand which standards of equity can meet environmental justice requirements and how to operationalize them in ways that facilitate their inclusion in cost-benefit analyses. This may mean disaggregating analysis of costs and benefits to the local level.

**Proposed Research**

1. Identify the most common concepts of equity, summarize how they have been applied in practice and evaluate their consistency with environmental justice standards. Perform a literature search and survey current practice.
2. Synthesize a proposed equity definition that is consistent with environmental justice principles. Circulate proposed definition(s) among representative practitioners, legal staffs, and interest groups for input.
3. Develop a set of indicators that can be used to determine equity in transportation projects and policy impacts consistent with environmental justice principles. Circulate proposed indicators among representative practitioners, academic researchers, and interest groups for input. Test potential indicators for effectiveness in practical applications.
4. Where possible, develop value measures for these indicators appropriate for use in cost-benefit evaluations. Test proposed measures for utility in cost-benefit analysis, consistency with NEPA and other environmental justice requirements, and the effectiveness in capturing the differential values (positive and negative) of project- and policy-induced changes.

NOTE: This research is a complement to "A Quantitative Approach to Define and Measure 'Equity' for Public Transit Investment Decision-Making," the concluding Research Needs Statement in this section.

**Cost:** $250,000
**Duration:** 24 months

### 7. ASSESSING IMPACTS OF GOODS MOVEMENT ON COMMUNITIES

**Problem Statement**

There is an on-going consolidation in the goods movement industry of both major companies and the number of facilities. This is true across modes—in railroads, trucking, ports, and pipelines. The consolidation of facilities means more traffic along fewer corridors and through fewer and larger terminals. Historically, many terminals and shipping corridors are located near low-income or minority populations. A greater volume of goods can lead to greater impacts on nearby disadvantaged populations. Consolidation in the industry also means a greater mismatch between the global perspective of many modern industry players and the community perspective of the local jurisdictions in which the facilities are located. Larger corporations are less likely to understand or be aware of local community concerns or be able to interact with the community to mitigate impacts.

At the same time, there is a growing opportunity to investigate impacts from goods movement on disadvantaged populations. Historically, many statewide and metropolitan planning models did not include or predict specific or accurate data about commercial trips. Accordingly, it was difficult to look at the system effects of consolidation in the goods movement industry on specific populations within a state or metropolitan region. Since ISTEA, however, state and regional transportation planning agencies have become increasingly involved in measuring and planning for the movement of goods and well as the movement of travelers. The work of the last few years can provide the foundation on which an analysis can look at which populations are impacted by consolidation in the goods movement and to what extent they are impacted.

The work to date on how to integrate goods movement needs into transportation decision making, to work with other organizations across modes, and to reach beyond government to work with industry stakeholders has not provided information on how to identify impacts on traditionally disadvantaged populations and communities.

To the extent that the transportation planning community is already developing methods to account for goods movement in regional and statewide planning, this research would build on that base of work to look at methods for analyzing the impact of goods flows as part of environmental assessment.

**Proposed Research**
The purpose of the research is to identify appropriate methods for assessing the impact of specific goods movement on potentially impacted populations and communities. This research will (1) begin with a search of existing literature on the measurement and planning for goods movement; (2) follow with a scan of current practices used with respect to (for example) environmental, socio-demographic, regional, and modal factors; and (3) continue with an assessment of the effectiveness of the methods identified above. This research also should include an economic analysis of changes in the location of entry-level, transportation-related jobs.

**Cost:** $250,000
**Duration:** 18 months

### 8. Improving Data, Methods, and Models for Assessing Transportation Impacts on Disadvantaged Populations

**Problem Statement**
Many state transportation departments and other regional and local transportation agencies are attempting to assess the impacts of transportation on traditionally disadvantaged populations from planning to project development. Much of this work has been in response to questions asked by community groups or public officials.

Although some of the questions about benefits and burdens can be answered, the ability to answer other questions is hindered by limitations in data, their use in models, and their interpretation by decision making. Many data sets and analytic methods used in transportation analysis today are based on methods designed in the 1950s. Although demands on decision makers to be aware of impacts, including impacts on disadvantaged populations, have become increasingly complex, our modeling templates have not. Some of the data and modeling limitations include

- Changes in population and employment demographics including a more racially and ethnically diverse population and increased dispersal of employment locations;
- Changes in travel patterns including more modal choices, increased travel to destinations other than work and more travel during off-peak times; and
- Lack of information about how the rate of chance influences the usefulness of data.

There is a need for research to support data and methods that can respond to contemporary questions about the impacts of transportation facilities on disadvantaged populations.

**Proposed Research**
The proposed research includes four sequential tasks.

1. *Demographic data*—Identify state, regional, and local practices that supplement census demographic and economic data. Data sets include information about race, ethnicity, and income for place of residence and place of employment.
2. *Travel behavior*—Identify state, regional, and local travel survey practices that supplement census data useful for assessing impacts of the transportation system on disadvantaged population knowing that the Census Transportation Planning Package will be available in 2003.
3. *Frequency of data collection*—Investigate the extent to which the frequency of data collection is sufficient for providing analysts and decision makers with accurate information on which to assess the impacts of transportation projects on disadvantaged population. Different frequencies will likely relate to the rate of change in different types of areas (e.g., sunbelt vs. rustbelt, exurban vs. central city). This task will also provide insight into the ability to project future changes.
4. *Cost benefit*—The final task will be to assess the extent to which the data collection and modeling, as described in the previous tasks, can affect the quality of cost-benefit analyses by adding information on disparate impacts on disadvantaged population.

**Cost:** $650,000
**Duration**: 48 months

**9. SYNTHESIS TOPIC PROPOSAL: APPLYING SOCIAL SCIENCE METHODS TO IDENTIFY COMMUNITIES AND MEASURE COMMUNITY COHESION FOR TRANSPORTATION PROJECTS**

**Problem Statement**
Consideration of transportation project impacts on communities and community cohesion has been required since the Federal Aid Highway Act of 1970. These topics have been the subject of increased interest, with the focus on CIA and environmental justice (EJ) analysis.

Potentially significant social impacts can drive the environmental documentation process; therefore, tools and methods to expedite and improve these determinations are much needed. Social scientists in fields such as sociology and social psychology have invested substantial effort in developing quantitative and qualitative measures of communities and community cohesion. The transportation community can benefit substantially from the application of already validated approaches, rather than making large resource investments to develop and validate new approaches and methods.

**Proposed Research**
1. Identify a small number of existing methodological approaches for delineating communities and measuring their cohesiveness (preferably techniques that have been used over time). The contractor could initially identify researchers at universities or research institutes who routinely conduct community-level research using the U.S. Census and other surveys (e.g., the survey research center at the University of Michigan). It will be important to brief those researchers about transportation agencies' needs to identify communities and measure their

cohesion, and the agencies' staffing and resource constraints. This synthesis project needs to maintain a practical focus throughout.

2. Identify existing typologies of communities that have been developed in the social sciences (e.g., urban/rural, new/established), and assess their potential usefulness for CIAs in transportation.

3. Identify existing approaches for delineating communities using the Census and other readily available data sources.

4. Identify existing approaches for measuring community cohesion using survey and more qualitative research methods (e.g., focus groups, interviews with informal community leaders).

5. Identify an experienced group of practitioners responsible for CIAs and present the preliminary findings to them. Incorporate their insights about using the identified approaches and data sources within the typical staff and resource constraints of DOTs, other modal agencies, and MPOs. As indicated, subsequently discuss the possibility of using modified approaches or data sources with the (university) researchers most familiar with them.

6. Categorize the resource requirements (high, medium, low) for DOTs, transit and modal agencies, and planners to use the above-identified methods, identifying opportunities to use already collected data that are publicly available, and noting any special requirements or considerations (e.g., access to a particular survey data set that is not census-based). Identify which approaches/data sources may be best suited for CIAs under particular conditions (rural community, highway project, etc).

**Cost:** $300,000
**Duration:** 2 years

## 10. To What Extent Do Motor Vehicles Affect Asthma and Respiratory Health?

### Problem Statement

There has been considerable notice in the press and questions raised by the public about the influence of motor vehicle emissions on increased rates of asthma and other respiratory illnesses. Health researchers and policy experts have identified increases in asthma rates and other issues of respiratory health with race, ethnicity, and income and frequently cite motor vehicles as a contributing factor.

Although researchers have recently published a large number of papers and appear to be reporting on the issue at an increasing pace, many of the results are difficult to understand. Furthermore, researchers using different methodologies have come to varying conclusions.

Given the number of papers, various research methods employed, and the variety of conclusions reached, it is difficult for transportation professionals to understand what actions they can or should take to respond.

### Proposed Research

This research is comprised of the following tasks:

1. The research will begin with a synthesis of existing health research cataloguing and categorizing published, peer-reviewed health research to identify when and to what extent mobile source emissions are included as a potential contributor.

2. The researchers will then scan current relevant health research, looking at what organizations and stakeholders are currently involved in this research.
3. The research will conclude by looking at the ability of the research to disaggregate impacts by:
    - Small area geography;
    - Race, ethnicity, income, and travel behavior; and
    - Transportation and access to health care.

**Cost:** $150,000
**Duration:** 15 months

## 11. Developing Performance Measures to Evaluate the Effectiveness of Engagement Processes in Meeting Public Involvement, Community Impact Assessment, and Environmental Justice Goals

### Problem Statement

Today, transportation agencies use public involvement programs to incorporate public input into more and more decisions. Sometimes agencies view public involvement as a way to make better decisions and enhance the acceptability of controversial projects. Other times, legislative and regulatory mandates such as those stemming from the NEPA, ISTEA, and reauthorized in TEA-21 require public involvement.

The meaningful engagement of the public is a clear link between CIA, Title VI, environmental justice, and public involvement processes. How we involve the public, how we define their communities, and how we treat them in a fair and equitable (nondiscriminatory) way is the key to ensuring that transportation problems and solutions are addressed in the spirit of existing laws, regulations and guidance.

Whatever the reasons, transportation agencies, decision makers, and the public are spending increasing amounts of time, energy, and resources developing and implementing public involvement programs. Despite these efforts, there are still indications of community dissatisfaction. Communities feel disempowered, are overwhelmed by government processes, and resent the seeming disconnect between their expressed concerns and transportation decisions.

What are appropriate performance measures for these processes? How can we tell if these public involvement programs are effective, and, where applicable, meet the goals of CIA and environmental justice?

### Proposed Research

Review program evaluation literature to identify a variety of approaches for assessing the effectiveness of engagement programs in meeting public involvement, CIA, and environmental justice goals. Define potential indicators of effectiveness and measures that can be used to assess performance of engagement programs against these indicators. In identifying indicators, consider such factors as:

- Accessibility to the decision-making process;
- Diversity of stakeholders and views represented;
- Range of opportunities for participation;

- Integration of community concerns in decision making;
- Integration of data provided by stakeholders on community conditions and impacts;
- Effectiveness of information exchange in stimulating participation, including cross cultural contexts;
- Duration of process;
- Mutual respect and learning among participants;
- Cost avoidance for affected agencies;
- Participation and opportunity time costs for participants; and
- Participant satisfaction with process and outcome/product.

Incorporate indicators and measures that reflect consideration of different perspectives; the assessment, including the sponsoring agency; other affected agencies; program participants; and nonprogram participants. Organize these indicators and measures into one or more assessment tools and pilot test them on a range of engagement programs, including those associated with long-range regional planning, corridor planning, state transportation improvement plan programming, urban project development, and rural project development. Based on pilot test findings, recommend assessment measures deemed most effective for various types of engagement processes. Prepare a guidebook to assist transportation agencies in conducting assessments of their engagement programs.

In addition, the research should provide success stories from the technical evaluation of the pilot tests. Examples should illustrate effective tools for engaging the public in providing data useful for impact analysis.

The research should ultimately develop guidance for practitioners to use in determining the best way to integrate public involvement, CIA, and environmental justice outreach in planning and project development processes to reduce project delays, enhance the quality of decisions, and eliminate duplication.

**Cost:** $450,000
**Duration:** 3 years

## 12. Remedies to Address Adverse Community Impacts from All Modes of Transportation

### Problem Statement

Many communities across the country have suffered adverse impacts from transportation projects of all kinds, including impacts from past projects and increase use of existing facilities [such as increases in freight (truck traffic), rail activity, and airport activity]. There has been a large disconnect between community inputs and their use by transportation decision makers. Most communities and their inhabitants often feel a sense of community disempowerment with the government and decision makers. Some decision makers are asked to provide mitigation measures in their present transportation decision making, whereas others are being asked to consider mitigation measures from past adverse impacts that were never mitigated.

Current state-of-the-art practice in assessing social and economic impacts is called community impact assessment (CIA). CIA is an evolving process of understanding the effects of transportation on communities including such things as barrier effects, noise impacts, and community cohesion. A significant component of understanding community impacts involves examining the effects of transportation projects upon a community's social capital.

Social capital is defined by Francis Fukuyama in *The Great Disruption* as

> A set of informal values or norms shared among members of a group that permits cooperation among them. The norms that produce social capital must substantively include virtues like truth telling, the meeting of obligations, and reciprocity. Social capital allows the different groups within a complex society to band together to defend their interest, which might otherwise be disregarded by a powerful state.

Fukuyama suggests that one approach to measuring social capital is to "measure the absence of social capital through traditional measures of social dysfunction such as crime, family breakdown, drug use, litigation, suicide, and tax evasion."

Measuring the benefits to society of projects that employed mitigation measures to those that did not could reveal to decision makers critical information about possible consequences that affect an area's economic interests and what mitigating measures are effective. Social capital can be used as a reliable quantitative measure of the economic consequences of community instability. Ultimately, the research should create a substantive bridge between economic success and social function success.

**Proposed Research**

The proposed research could be completed in two phases. Phase I could include the collection of data that measures social capital of communities before and after transportation projects. Completed transportation projects could be selected through a survey of state DOTs, transit agencies, railroad operators, airport facilities, etc. Phase II could include guidance and best practices to practitioners on remedies that should be included in current transportation decision making, as well as remedies to address past transportation decision making.

**Cost:** $350,000
**Duration:** 24–36 months

**13. The Role of Public Involvement in Environmental Streamlining**

**Problem Statement**

Section 1309 of the TEA-21 directs the U.S. DOT to streamline environmental review. To date, most of the effort has been directed toward streamlining the permitting and other interagency coordination processes to speed project approval. Very little attention has been given to how public involvement processes affect environmental streamlining at both the planning and project development stages. There are many unanswered questions regarding the extent to which public involvement supports or undermines the goals of streamlining–to reduce the cost and delivery time of transportation projects.

Practitioners often claim that public involvement programs save time and project costs in the long run by identifying issues early in the process, thereby avoiding changes in scope later in the process. They also broaden the consideration of alternatives by addressing community goals and reducing the potential for delay caused by litigation. Others perceive that public involvement programs extend the time frame of projects and increase project costs by adding more elements. Research is needed to provide data on the impact of public involvement on project delivery timeframes and ultimate project cost.

**Proposed Research**
The proposed research would involve

1. Selection of a national sample of projects across all modes categorized by type, project development cost, construction cost, level of controversy, and complexity of design elements.
2. Characterization of the nature and extent of the public involvement process for each project, identifying strengths and weaknesses as appropriate.
3. Determination of the timelines from project conception through project development to commencement of construction.
4. Comparison of the matrix of projects and determination of how the variable of public involvement affects the development duration and overall cost.
5. Development of conclusions and recommendations to project development agencies at the national, state, and local levels. These should reflect qualitative as well as quantitative effects of public involvement on the development process.

Case selection should be focused on instances where the public's satisfaction or dissatisfaction with opportunities for input and use of their input by decision makers had a major effect on the project timeline. Matching cases that are very similar on most dimensions except the quality of the public involvement program for a paired analysis would enhance the usefulness of the research findings.

**Cost:** $400,000
**Duration:** 24 months

### 14. COMMUNITY IMPACT ASSESSMENT, PUBLIC INVOLVEMENT, AND TITLE VI/ENVIRONMENTAL JUSTICE: STREAMLINING MULTIMODAL TRANSPORTATION PROJECTS THROUGH PRACTITIONER EXPERIENCE

**Problem Statement**
Transportation projects are becoming increasingly more complex because of the multimodal (highways, rail transit, freight rail, pipelines, etc.) aspect of the industry. There is a large body of work concerning single modes of transportation; however, more research is needed on aspects of multimodal issues. The renewed commitment of transportation practitioners to address the impacts of their projects on the community has created many challenges. CIA, Title VI/environmental justice, and public involvement should be considered during development of the Statewide Transportation Improvement Program and the Metropolitan Transportation Improvement Program, as well as project development of publicly and privately funded projects. Because of the decisions made during planning that distribute funds to sets of projects, knowledge of and involvement of environmental justice communities in planning is critical. In an effort to streamline this process, practitioners need a direct and compelling means to expand their expertise and learn the state of the practice from each other. Practitioners, local officials,

and the public can all benefit from CIA, public involvement, and Title VI/environmental justice information when presented in a clear, user-friendly form.

**Proposed Research**
Best practices must be determined to assist transportation practitioners in streamlining and addressing multimodal transportation issues as they relate to new transportation initiatives and projects. Informational tool kits are to be developed in the form of handbooks, which would include an overview of the various transportation modes and research findings, including guidelines for communities to consider when developing around various transportation modes as well as guidelines for transportation practitioners when proposing projects in communities. Research into the following best practice issues and questions that will be necessary include

- How to conduct a CIA during long-range, system planning throughout project development;
- Situations or criteria that indicate when CIA should be re-evaluated;
- How to better use public involvement and assess CIA and Title VI/environmental justice;
- Synthesizing research on ways to define community and community boundaries, as well as determine community cohesion;
- Investigation of how best to identify and assess secondary and cumulative impacts; and
- Guidance for local land use planners on anticipated impacts of locating projects near multimodal corridors, such as light and heavy rail transit and freight rail.

These best practices would cover examples and information applicable to urban, suburban, and rural communities for use in the development of the informational tool kits.

**Cost:** $300,000
**Duration:** 24 months

### 15. A QUANTITATIVE APPROACH TO DEFINING AND MEASURING "EQUITY" FOR PUBLIC TRANSIT INVESTMENT DECISION MAKING

**Problem Statement**
Environmental justice seeks to ensure that actions and policies, particularly by public agencies, do not result in "disproportionately high and adverse effects" on minority and low-income populations and communities. Also frequently referred to as "social equity," the term is widely used but not often well understood. Although environmental justice seeks to ensure fairness and nondiscrimination, it does not ensure "equality." Public agency decisions may result in challenges on the basis of conflicting "values" among community representatives and interest groups. An important issue that needs to be better addressed, particularly for public transit investment decisions, is the distribution of benefits and burdens, and of costs and subsidies, within and among various population groups and geographic areas. These choices necessarily involve political and "value" determinations that have been facing increasing challenges from traditionally underserved communities that desire a greater share of available funding. Is it "fair" that a relatively affluent suburban rail commuter benefits from an average total subsidy per ride of up to $100, whereas the average urban bus rider, most commonly a lower-income person of color, has a trip subsidy of maybe $2 to $5? In addition, the ongoing challenge of welfare

reform requires that improved mobility options and delivery methods be more readily available for the working poor who are seeking to access nontraditional employment times and places, such as late-night service jobs.

Although some work has been done to address subsidy inequities for automotive travel, there is little documentation and no common agreement regarding how to define or measure "equity" between various public transit modes. This research would provide a basic definition and framework for such evaluations.

**Proposed Research**

A cost-benefit analytical approach is proposed, including

1. An initial literature search, including an inventory of administrative and litigation actions to date seeking to change transit-funding actions.
2. Identification of costs and subsidies by public transit mode (urban bus, light rail, heavy rail, commuter rail, rural systems) for a representative sample of systems. Full costs include initial capital, annual operations and maintenance, and replacement.
3. Identification of users, beneficiaries (including secondary level), and payers.
4. Identification of mobility, social, and environmental impacts to geographic communities and stakeholder groups. Identification of value or detriment to communities resulting from elimination or reduction of services or project.
5. Determination of how to assign costs to identified benefits.
6. Development of supportable definition(s) of "equity."
7. Proposal of criteria, measures, and indicators for assessing equity of outcomes from transportation investment decisions.

NOTE: This research is a complement to """Establishing Equity Measures for Cost-Benefit Environmental Justice Analysis."

**Cost:** $350,000
**Duration:** 30 months

Collaborative Research Needs Statements

**16. CUMULATIVE, AREAWIDE, AND INDIRECT IMPACTS OF TRANSPORTATION**

For full text, see Statement 12 under Sustainability, Including Climate Change: Cause and Effects.

**17. AIRCRAFT NOISE HEALTH EFFECTS STUDY**

For full text, see Statement 8 under Noise

**18. STUDY OF COMMUNITY RESPONSE TO NONAIRCRAFT TRANSPORTATION NOISE**

For full text, see Statement 5 under Noise

**19. RESEARCH ON HELICOPTER NOISE IMPACTS TO THE COMMUNITY**

For full text, see Statement 11 under Noise

# Context-Sensitive Design, Including Aesthetics and Visual Quality

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RESOURCE PAPER

# Context-Sensitive Design, Including Aesthetics and Visual Quality

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## INTRODUCTION

Context-sensitive design (CSD) is a process for providing transportation solutions that simultaneously advance the objectives of safety, mobility, enhancement of the natural environment, and the preservation of community values. In short, CSD represents design excellence. The current focus of "Context-sensitive Design" in transportation has evolved from two distinct shifts in the engineering project design paradigm. First, the nation and most states have shifted administratively from a narrow highway focus to a broader view of transportation. This recognizes links between all modal transport types in the transportation network. Second, there is an increasing demand on the part of stakeholders and users for a system that is more attractive, sensitive to the cultural and natural environment, and that considers the values of affected communities, while maintaining the safety and mobility needed to support a vibrant economy.

Recognizing the shift in focus at the national level, the American Association of State Highway and Transportation Officials (AASHTO) issued a policy statement significant to CSD in the *National Highway System (NHS) Design Standards.* This publication made clear AASHTO's better understanding of public involvement as a key element in the transportation delivery process. This policy resolved to

> …work through AASHTO's design standards committees with DOT and with interested parties on design criteria and a design process for NHS routes that integrate safety, environmental, scenic, historic, community and preservation concerns, and on standards which also foster access for bicycles and pedestrian traffic along with other transportation modes.

Many other important works have contributed to the present ideology influencing CSD, some of which include:

- *Flexibility in Highway Design,* FHWA-PD-97-062. Federal Highway Administration, U.S. Department of Transportation, 1997.
- "Policy on Geometric Design of Highways and Streets," AASHTO, 2001.
- "Thinking Beyond the Pavement: A National Workshop on Integrating Highway Development with Communities and the Environment While Maintaining Safety and Performance," conference, Maryland Department of Transportation, State Highway Administration.

Several other national transportation venues have built on these foundations including:

- American Society of Civil Engineers—Virginia (1999);

- FHWA co-sponsored Western Region CSD Workshop—Montana, and Northeastern Region CSD Workshop—Connecticut (both in 2001); and
- Formation of an AASHTO National Steering Committee and CSD Action Plan.

At least 16 states have sponsored CSD conferences or training.

The issues of CSD are most closely associated with the environment, safety, and geometric design. However, CSD really transcends all aspects of transportation project planning, design, construction, operation, and maintenance. Because the issues are so broad, this paper focuses only on setting the stage for establishing CSD research needs in the areas that impact natural and cultural environmental concerns.

## CONCEPTS, PRINCIPLES, AND MEASURES OF CONTEXT-SENSITIVE DESIGN

The intent of this section is to explore the concepts of CSD, the principles by which success may be measured, and the tools being employed to achieve design excellence in transportation.

### Concepts of CSD

Two broad concepts are central to CSD:

- Each transportation project is unique; that is, the site, circumstances, users, and value systems of the stakeholders are different than any other project regardless of similarities.
- The design response must be crafted to meet the unique characteristics of the site and the stakeholders.

In general, practitioners accept these concepts as being “business as usual.” However, in practice, designers have a tendency to return to what worked before and solutions that appear to be “safe.” Given the litigious nature of the practice environment, the motivation for using a “cookie cutter” approach of time-tested standards is easily understood; however, widespread public resistance to standardized solutions gives ample evidence that this mentality is simply no longer acceptable.

Clearly there are many design considerations of the transportation network that do require uniformity to ensure safety and operational efficiency. Signals and markings need to be standardized to communicate clearly and avoid confusion; the geometric properties of the traveled way must be set to accommodate the speed and types of vehicles that use them; roadside features must be designed to minimize the potential for injury. However, beyond these basic parameters, there are almost unlimited degrees of freedom.

### Principles of CSD

The Maryland workshop on “Thinking Beyond the Pavement” developed eight principles that clearly articulate the foundation of the CSD project delivery process. These principles were labeled as the “characteristics” of the process:

- Communication with all stakeholders is open, honest, early, and continuous.
- A multidisciplinary team is established early, with disciplines based on the needs of the specific project and with the inclusion of the public.

- A full range of stakeholders is involved with transportation officials in the scoping phase. The purposes of the project are clearly defined and consensus on the scope is forged before proceeding.
- The highway development process is tailored to meet the circumstances. This process should examine multiple alternatives that will result in a consensus of approach methods.
- A commitment to the process from top agency officials and local leaders is secured.
- The public involvement process, which includes informal meetings, is tailored to the project.
- The landscape, the community, and valued resources are understood before engineering design is started.
- A full range of tools for communication about project alternatives is used (e.g., visualization).

These principles require constant communication with the stakeholders and being responsive to their values and the unique conditions of the site. Although it sounds simple, the actual practice is complex. In an article for *Public Roads*, Peaks and Hayes cited a post-construction survey in which users were asked to rank the most important characteristics of a new freeway. In the survey, participants living adjacent to the freeway ranked noise, fumes, and appearance as the top three characteristics. This same group ranked congestion, design standards, and travel times at the bottom of the list. Those responding to the survey that lived away from the freeway ranked the same characteristics in the opposite order.

Because perceptions of need and purpose for projects can be very diverse and often diametrically opposed it is critical that project managers be skilled in conflict resolution and have access to a multidisciplinary team with appropriate technical skill and knowledge to address the unique problems of each project.

**CSD Measures of Design Excellence**

The “Thinking Beyond the Pavement” workshop went on to describe seven measures of design excellence for transportation projects. These measures provide a fundamental yardstick for evaluating the success of a project in meeting the CSD principles:

- The project satisfies the purpose and needs as agreed to by a full range of stakeholders. This agreement is forged in the earliest phase of the project and amended as warranted as the project develops.
- The project is a safe facility for both the user and the community.
- The project is in harmony with the community and it preserves environmental, scenic, aesthetic, historic, and natural resource values of the area; i.e., exhibits CSD.
- The project exceeds the expectations of both designers and stakeholders and achieves a level of excellence in people's minds.
- The project involves efficient and effective use of the resources (time, budget, community) of all involved parties.
- The project is designed and built with minimal disruption to the community.
- The project is seen as having added lasting value to the community.

The workshop established a very clear vision of what CSD is about. The subsequent pilot project for implementation will provide further guidance in institutionalizing the CSD process.

Unfortunately, the results of TRB Project 15-19, FY 2000, *Application of Context-Sensitive Design Principles,* were not available for review and discussion.

This notwithstanding, the benefits and the roadblocks to implementing the CSD process are reasonably clear. What appears to be lacking is documentation of actual experiences in implementation, along with the development of frameworks and tools for implementation. These broad topics represent the most likely areas for future research.

**Frameworks for Institutionalizing CSD**

CSD is actually the reformation of the entire transportation delivery process. In many cases the project delivery process is seen as linear (Figure 1). In its simplest form it involves programming, planning, design, construction, operation, and maintenance. One only has to look at the organizational makeup of a state transportation agency to see that this is still a ubiquitous model. This organizational format is for the most part logical. However, with respect to the project delivery process, it can be very unresponsive if it is viewed as a sequence in time. That is, the planners plan, and then turn the plan over to the designers who design, designers then pass the project on to the contractors who build a product, which is then turned over to operations and maintenance personnel. This model is not responsive if communication is not maintained throughout the process both internally and externally.

The CSD process recognizes that the project delivery process is iterative and that communication must be maintained between all stakeholders (Figure 2). To accomplish this there must be a framework established that maintains communication with stakeholders throughout the project delivery process.

Efforts to institutionalize CSD within state transportation agencies are generally structured around programs of education and training in CSD. In addition to education many include careful review of existing enabling statutes, directives, and in-place project delivery processes to identify and remove roadblocks to CSD implementation.

These efforts demonstrate that the transportation industry is recognizing the need for a critical paradigm shift away from the old model of "Design ... Defend ... Redesign ... and, often, … Defend, and Redesign again." Whereas the new CSD paradigm is "Listen and completely understand the context ... then Design … and …Build" without going back to the drawing board. This is the time and money saving benefit that accrues from CSD. Although these benefits are intuitively understood little has been done to quantify these potential or actual savings.

**Education and Training**

Each state has adopted different approach to CSD training programs. The elements of most programs however include

- Project development and management,
- Public involvement and facilitated communication,
- Environmental management,
- Geometric design and design guidelines,
- Tort liability, and
- Aesthetics/visual resource management.

This content must be tailored to the operational and organizational styles of the individual agency.

### Identification of Institutional Roadblocks

Within each state there are institutionalized mandates that direct how an agency does business. In many cases these mandates effectively prevent the application of CSD principles. For example, some statutes have prescriptive language that governs highway configuration and design. These situations must be identified and appropriate strategies developed to mitigate antiquated regulations. When discussing current practice and changing long-standing standards and statutory mandates there are sometimes misconceptions about what CSD does. It is very important to note that CSD does not

- Compromise standards or safety,
- Create “us versus them” and “winners versus losers” situations,
- Listen only to the loudest voices,
- Do what each stakeholder wants, and
- Spend much more time and money.

## TOOLS

Tools, as used here, refers to specific activities or design principles that can be used to understand the design context and help define and satisfy client and stakeholder transportation needs. Because CSD is really a broad-based approach to the transportation delivery process and because that process involves every aspect of programming, financing, planning, design and engineering, construction, operations, and maintenance, research associated with CSD is probably best defined when related to more specific tools used in implementation. This section discusses some of the most prevalent CSD tools that may lend themselves to meaningful research.

### Traffic Calming

Traffic calming has become popular as a tool for increasing safety and reducing traffic noise and speed in established neighborhoods and historic commercial districts. There is a great deal of information available on actions that can be taken to reduce traffic volume and speeds that range from constriction of driving lanes at intersections to traffic circles (Figure 3) and limiting access. Although the concept of traffic calming is highly touted as a means to create more desirable “user friendly” spaces within neighborhoods and communities, the only substantive post-construction evaluation of these tools has been conducted in Western Europe. These results do not necessarily translate to U.S. culture. Likewise, little is known about the economic impact and safety performance of many traffic-calming strategies. For example, the concept of placing small circular islands to create roundabouts is not well understood and often becomes a driving hazard rather than a traffic control. The FHWA has two studies underway in the area of traffic calming that have not been released. These may answer some of the questions and may point to other areas needing further research. When taken in the context of an aging population and the need to integrate better pedestrian facilities into many neighborhoods, traffic calming will likely remain an area needing additional research for sometime.

### Aesthetic Design Treatment

The aesthetic quality, or lack thereof, of public works and the transportation system in general has resulted in considerable resistance from stakeholders and users of the system. In a vast majority of cases where public resistance to transportation projects is encountered, much of that resistance is based on the perceived aesthetic quality of the product being proposed. In this regard, it is important to understand that aesthetic quality tends to be a shared cultural value that may be related to local or neighborhood perceptions or user expectations. These values are often difficult to capture and successfully integrate into projects.

Some states have tried to approach the aesthetic issues of transportation projects with a cookbook mentality. However, the cultural differences in visual preference are not likely to be effectively addressed by an "aesthetics cookbook." The tool that seems to offer the greatest success in cost-effectively addressing aesthetic issues is the public participation process. Post-project satisfaction studies and the development of better tools for the public participation process, to deal with aesthetic issues, will likely be fruitful grounds for further research.

**Cultural Resource Management**

Cultural and historic resources are frequent obstacles to transportation projects. These types of resources (Figure 4) are not always obvious or easily understood without the help of the local community. Once identified the relative cost of conserving these resources can be prohibitive for a variety of reasons including building codes, material availability, utility, and location.

A variety of tools have been developed, but there is often a gap between the transportation community and the cultural resource interests in a community. Two areas that appear to offer the greatest potential to successfully address cultural resource issues in transportation are the public participation process and information technology. A public participation process can be used effectively to identify public and stakeholder concerns for cultural resources, as well as to negotiate means to preserve or conserve the resources of concern. Information technology offers the best means for providing data that will help transportation programmers and planners to identify and avoid cultural resource conflicts early in the project delivery process.

The use of information technology, particularly web-based applications, appears to offer the economic means to gather and disseminate cultural resource information and appears to be an area for meaningful investigation.

**Visual Resource Management**

Visual resources are often lumped together with aesthetics; however, it is quite a different part of the CSD puzzle. Visual resources refer to the greater landscape (Figure 5). That is, the landscape that extends far beyond the right-of-way line. Most frequently the issues related to the visual resource are the view of the road as opposed to the view of or along the road. Most of the dramatic examples of visual resource management are seen in projects like Glenwood Canyon where the spectacular scenery is easily damaged or permanently changed by corridor construction. Figure 5 shows a good example of the best and the worst as far as visual change. In the foreground and middle ground, both corridors hug or fly over the existing landscape, whereas in the background the alignment runs through a massive rock cut.

The research needed in the area of visual resource management is most strongly related to issues of design flexibility, which will be discussed more in a later section.

**Public Participation**

Involving stakeholders in the project development and delivery process lies at the heart of providing "context-sensitive solutions." Final success and product quality are inexorably linked to how it is received by the clients and users. In a planning and design environment where there is no clearly defined end user and where responsibility resides in a political entity rather than an individual, it is usually very difficult to clearly scope a project and identify all the constituencies that will be impacted without a well-designed program of public participation.

Although the validity and need for public participation in the project development and delivery process has become more widely accepted by transportation officials, the means for implementing the process and using the findings may often be poorly developed and not well understood. There is substantial literature in the area of public participation and conflict resolution; however, this information is often not being translated and transferred into transportation practice. This issue is clearly at the root of the CSD movement in transportation.

It is probably fair to say that effective public participation and communication is potentially the weakest link in every aspect of the process. Successfully delivering a quality product in a controversial environment is dependent on systematically developing and maintaining "informed consent." For this reason research in public participation is needed to extend and refine research that has been done in other venues and to translate the public participation tools into transportation practice. One important part of this research would be the translation of a largely social science research base into a design and engineering compatible language.

**Flexibility in Design**

Flexibility in design is often cited as another term for CSD. However, in the framework of transportation practice as defined by AASHTO, flexibility in design has come to have a somewhat narrower definition than CSD, in that it tends to focus on the following specific physical areas of concern:

- Safety,
- Geometry,
- Aesthetics, and
- Tort liability.

AASHTO's *A Policy on the Geometric Design of Highways and Streets*, the "Green Book," strongly influences the physical design of highways in this country. Although the publication clearly states that it is a guide, it is often held out as a standard. This interpretation has led to a perceived level of inflexibility in design. To mitigate this perception and to deal with the legitimate concerns of safety, geometrics, aesthetics, and liability, the AASHTO Standing Committee on Design is currently working on a supplemental publication or publications to address these concerns.

On the other hand, it is doubtful that a supplemental publication to the "Green Book" will really allay all of the concerns, particularly in the area of tort liability. Concerns over the liability for the design of any structure below optimum configuration are understandable in the current legal environment. For this reason, there may be a need for substantive research that demonstrates the safety and utility of facilities designed to the minimum rather than optimum standard. This is essential to encourage design exploration.

## POPULAR MOVEMENTS RELATED TO CSD

These are movements that have gained popularity and have some common ground with CSD in transportation. In general, they focus on concepts and issues of urban living rather than values common to rural communities, or what might be termed scenic landscapes. Each of these movements represents an organized voice that can be an important source of information when defining the scope of a project. It is equally important to understand that each of these movements represents a single point of view and may not necessarily represent the broader community of stakeholders.

### Livable Communities

This is a term popularized during the last national administration that focuses on developing those components of the urban environment that make a community more people friendly, and therefore more livable. It focuses on issues of neighborhood, and particularly stresses the use of alternative transport modes (i.e., public transit and bicycle pedestrian).

### Sustainable Transportation

Sustainability is becoming an extremely popular concept, particularly as it relates to the environmental concerns. The emerging focus of this movement is at the macroscale, which is often beyond the scope of traditional transportation practice. Conversely, sustainability concepts stem from maintaining a standard of living without depleting the natural resource base. Clearly the availability and use of natural resources impacts the environment and ultimately the transportation system. To this extent, a component of the research needs agenda in CSD may wish to address issues of sustainability related specifically to the long-term utility of the transportation system.

### Smart Growth and New Urbanism

These movements are focused on curbing urban growth. Advocates blame urban growth with many of the problems faced by major urban centers including blight and a declining tax base. Smart growth proponents recommend concentrating growth and population through a variety of land use controls and incentives. Proponents hold that in-fill and increased densities reduce the costs of construction and maintenance of infrastructure and make mass transportation more viable and cost-effective.

These ideas and principles remain controversial, but they have great influence on many decision makers. Therefore, the concepts espoused by these movements may be used as a guide for developing transportation research that will document the relative validity and lead to strategies for adjusting transportation design criteria to meet a changing development philosophy.

## CONCLUSIONS

The concept of CSD, although not new, as demonstrated in the literature, is extremely broad in scope. It touches on all aspects of transportation development and therefore needs definition and further exploration. The scope of CSD is not just environmental and does not fall in the domain of any single discipline. CSD principles require a team approach to be implemented successfully.

The purpose of this presentation has been to develop the background and context of the CSD movement and has pointed out some broad areas that seem to warrant further investigation.

The report has deliberately avoided suggesting specific research needs. That is for the focus group in CSD to accomplish at the March meeting in Washington, D.C. It is hoped that those that wish to participate in developing research needs in CSD will find the resources listed in the reference section useful in framing ideas and concepts needed to develop statements of detailed research needs.

## REFERENCES AND OTHER RESOURCES

Brewer, J., et al. *Geometric Design Practices for European Roads*. American Trade Initiatives, Office of International Programs, Federal Highway Administration, Washington, D.C., 2001.

The objective of the scanning tour was to review and document European procedures and practices in roadway geometric design and context-sensitive design, in which a balance is sought between safety and mobility needs and community interests. The U.S. group visited sites in Sweden, Denmark, The Netherlands, England, and Germany, and met with numerous representatives from transportation and highway ministries, research organizations, and consultants. In the European countries, the general philosophy for highway design and project development is to develop a transportation program and system that enhances community values and integrates roadways into communities and the environment. This philosophy is supported by very high safety goals. The U.S. delegation found potentially transferable practices regarding public involvement in project planning; self-explaining, self-enforcing rural roads; design flexibility; area-wide traffic calming measures; intersection control through roundabouts; and integration of bicyclists and pedestrians.

*Environmental Successes in Transportation Project Development.* American Association of State Highway and Transportation Officials, Washington, D.C., 2001.

This report contains 16 case studies of exemplary programs and projects now underway across the country designed to improve mobility and add to the quality of their surroundings. The projects are organized according to six successful practice categories: Process Management, Improved Scoping, Visualization Techniques, Technology Application, Context-Sensitive Design, and Conflict Avoidance and Dispute Resolution. These project practices and strategies should be of interest to those responsible for planning, programming, development, and design of highway projects.

McCormack, S. *Agents of Change*. World Highways/Routes Du Monde, 2001.

Although in developed countries environmental considerations are commonly employed when considering road planning management processes, the situation is considered to be different in developing and in transition countries, where poverty alleviation and industrial development can take precedence over environmental concerns. Such countries have to set their own priorities and resent developed countries trying to influence infrastructure investment decisions. Although transport infrastructure development is essential for market accessibility, and therefore employment, the World Bank considers that inappropriately designed transport strategies can harm the environment and aggravate the needs of the poor and public finance capacity. Environmental impact assessment studies, carried out by funding agencies, can increase project costs, but can also bring about increased awareness of environmental considerations even where they are not a main priority. In the United States, many states have introduced CSD when considering transportation projects that include environmental aspects.

Kramer, J., and K. M. Williams. "Community Impact Assessment: A Handbook for Transportation Professionals." *ITE 2000 Annual Meeting and Exhibit,* Nashville, Tenn*.,* Institute of Transportation Engineers, Washington, D.C.

The objective of this project is to provide practical, cost-effective, and community-driven methods for identifying, evaluating, and addressing community impacts that are oriented toward the practitioner. Transportation projects can have major social and economic effects—both positive and negative. Assessment of community impact provides insight into ways projects can be improved or redefined to reduce adverse impacts and increase overall project benefits, both for the affected communities and the traveling public. Community impact assessment also supports the intent of the National Environmental Policy Act (NEPA), the federal law governing the environmental decision-making process for federally funded transportation projects. Although NEPA places equal emphasis on both the natural and human environment, much of the attention in environmental impact assessment has been placed on the natural environment. In an effort to address that inequity, the Florida Department of Transportation (FDOT) is developing a community impact assessment program to provide equal attention to how transportation projects affect people and communities. The program is to be carried out primarily during the environmental assessment process, but has implications for the planning through construction stages. This effort coincides with the national movement toward CSD in the engineering arena and sustainable development in the planning arena. In support of the statewide community impact assessment program, the FDOT asked the Center for Urban Transportation Research at the University of South Florida to develop a handbook and provide training on community impact assessment.

Ewing, R. "From Highway to My Way."*Planning*, Vol. 67, No. 1, 2001, pp. 22–27.

This article describes the relatively new concept of context-sensitive highway design and how transportation planners are focusing on the links between transportation systems and surrounding land uses. New standards, policies, and scenic/historic laws applicable to main streets in several U.S. states and communities, within the context of planning and design that attempts to make roadways more community friendly, are provided and discussed.

Gavin, J. "A Road Runs Through It." *American City and County*, Vol. 115, No. 17, 2000, p. 5.

This article discusses the growing trend of cities and counties to redesign roads to make them more community and pedestrian friendly through the incorporation of public places into road and transportation planning. The practice has been termed context-sensitive design and is concerned with the manner in which streets and highways are routed through living spaces. Several tips for building context-sensitive roadways are listed, and examples of successful efforts across the United States are provided.

Gavin, J. “Building Livable Highways: Case Studies Show That There Is More to Road Design Than Just Getting from Point A to Point B.”*AASHTO Quarterly Magazine*, Fall, Vol. 78, No. 3, pp. 22–25.

Americans are beginning to realize that people need public places to gather to maintain some sense of belonging to a community. The way streets and highways are routed through living areas or redesigned to lessen any negative effects they may have on the livability of an area is the significant part of the mission of a movement called context-sensitive design. There are many success stories in the field of context-sensitive design from Springdale, Utah, where the relationship between Zion National Park and the nearest town was made positive by a redesign of the traffic flow through the town and the park; to Somerville, Massachusetts, where redesign of the traffic and pedestrian flow in Davis Square has turned Cambridge's ugly-duckling neighbor into a commercially viable swan; to Calabasas, California, where design steps that slowed down the raceway through town have sped up the commercial and pedestrian viability of the town. Other states that have taken the concept to new places include Florida, Oregon, Kentucky, Connecticut, Maryland, and New Jersey.

*Reducing the Impact*. World Highways/Routes Du Monde. Vol. 9, No. 6, 2000, pp. 44–46.

As population increases and more infrastructure is built to support it, the impact of human development on the environment increases. Today, engineers and contractors must ensure that a project is in as much harmony as possible with its neighboring communities and environment. With increasing frequency, an environmental impact study must be made before a road project can begin. In the United States, the FHWA and some states promote context-sensitive design principles. Effects of road projects and operations on the environment include the destruction of wildlife habitats, erosion, sedimentation, soil compaction, chemical pollution from de-icing, contaminated run-off, vehicle emissions, and the generation of a variety of waste materials. This article discusses (1) a pilot program where 10 transport projects in 7 U.S. states were selected to find ways of streamlining and accelerating transport improvements, while better protecting the environment; (2) the Transportation Environmental Research Program environmental agency, which will add to the understanding of transport and environmental issues through research and help to formulate new environmental policies; and (3) examples of ecological projects in the United Kingdom, the United States, and Canada designed to reduce the impact of road schemes on wildlife.

Myerson, D. L. “Getting It Right in the Right-of-Way: Citizen Participation in Context-Sensitive Highway Design.” *Scenic America*, Washington, D.C., 2000, p. 24.

This action guide includes information on community involvement in transportation planning, advises citizens on planning strategies for working with state highway engineers, provides basic road design vocabulary and information on federal laws that support context-sensitive design, and provides helpful case studies. Also included is a bibliography prepared by Sally Oldham.

Kassoff, H. “Making Design Context Sensitive.” *Roads and Bridges*, Vol. 38, No. 2, 2000, p. 20.

The highway design process has traditionally emphasized achieving required functionality at the lowest possible cost. Although this goal remains important, it has become increasingly clear that other factors contribute to gaining acceptance for highway improvements. Paying close attention to environmental impacts; committing to avoid, minimize, or mitigate these impacts to the maximum extent possible; and even finding ways to provide environmental improvements over existing conditions have become prerequisites for winning local community and environmental resource agency support. Also, the visual impact of a highway project has come to have a major bearing on its acceptance or rejection. Highway planners and design professionals are increasingly aware that the basic process by which highway improvements are planned and engineered is changing. They are embracing the notion that environmental and aesthetic issues must be dealt with as an integral part of the process from the outset. This article outlines why context-sensitive design is the preferred way of developing a project.

Lewis D. “How to Merge Yesterday's Roads with Today's Designs.” *Traffic Safety*, Vol. 99, No. 1, 1999, pp. 14–15.

When engineers proposed a plan to make Main Street in Westminster, Maryland, a 40-ft (12-m) roadway, removing 42 mature trees and leaving sidewalks at 5 ft (1.5 m), it sparked an atmosphere of combativeness in the community. Eventually, the project was redesigned to everyone's satisfaction. The road's cross section was reduced to 36 ft (11 m), which allowed for ample sidewalks, the preservation of 34 trees (plus 106 new ones), and an overall harmonious ambiance. The Westminster project has become something of a poster child for the context-sensitive design movement. The public wants more from engineers than just the straightest, flattest, widest road possible. The widespread literal adherence to the American Association of State Highway and Transportation Officials' “Green Book,” which contains the basic geometric design criteria for roadways and is a product of the "speed and mobility first" school of thought, seems to be at the heart of the issue. The public perceives engineers as rigid bureaucrats, whereas many engineers view the public as overly emotional "tree huggers." A sidebar discusses the next steps for context-sensitive design.

“Thinking Beyond the Pavement.” *AASHTO Quarterly Magazine,* Vol. 77, No. 3, 1998, pp. 27–34.

This conference was held at the University of Maryland Conference Center, College Park, Maryland, in May 1998. It provided an opportunity for 325 invited participants from 39 states and the District of Columbia to develop a vision of excellence in highway design for the 21st century. Conference planners sought to (*a*) find and publicize the best ways of integrating highways with their communities and the environment while maintaining safety and performance; (*b*) encourage continuous improvement in the design of transportation projects across the nation, balancing all of the public's concerns, whether transportation related or not; and (*c*) achieve flexible, context-sensitive design in all projects. Conference developments included (*a*) a consensus on the qualities of projects and the characteristics of the highway development process that could integrate transportation facilities with communities and the environment and (*b*) implementation of actions to overcome barriers to

context-sensitive design, educate transportation professionals and stakeholders on this approach to design, and encourage its application to all projects.

Maryland Department of Transportation. "Thinking Beyond the Pavement: A National Workshop on Integrating Highway Development with Communities and the Environment." University Of Maryland, College Park, Conference Summary, May 3–6, 1998.
The conference was designed to develop a consensus on the qualities of projects and the characteristics of the highway development process that could integrate transportation facilities with communities and the environment, develop implementation actions to overcome barriers to context-sensitive design, educate transportation professionals and stakeholders on this approach to design, and encourage its application to all projects. Three hundred and twenty-five individuals from 39 states and the District of Columbia, including representatives from 29 state DOTs, attended the conference. Three-quarters of the participants were transportation professionals, whereas the remainder consisted of transportation stakeholders representing public agencies, elected officials, private business, and citizen perspectives. The conference participants examined Project Case Studies to identify and articulate the purpose of each project and to explore the desired results and the community impacts. This *Conference Summary* includes the conference agenda, an executive summary, and the conference summary report.

### USEFUL AND INFORMATIVE WEBSITES

The following are websites that have useful information about issues related to context-sensitive design and livable communities. Many of these sites have links to other sites as well.

http://www.arrb.org.au/
http://goodneighbor.gsa.gov/goodnb/
http://www.cnu.org/
http://www.clfuture.org/
http://www.fhwa.dot.gov/csd/
http://www.pps.org/Transportation/csd_training.html
http://www.scenic.org/roads.htm
http://www.epa.gov/smartgrowth/
http://www.mainst.org
http://www.fta.dot.gov
http://www.lgc.org/center/index.html
http://www.sha.state.md.us/oce/thinking.htm
http://www.sonic.net/abcaia/narrow.htm
http://www.ntba.net
http://www.dot.state.ny.us/eab/eiexam14.html
http://www.newurbanism.org/page416429.htm
http://www.smartgrowth.org/
http://www.epa.gov/livability/index/sgi-home.html
http://www.transact.org/main.htm
http://www.tlcnetwork.org/
http://www.arrb.org.au/arrbtr/enviro.htm
http://www.pps.org/Transportation/livable_transportation.htm

http://www.washingtonregion.net/
http://www.walkable.org/

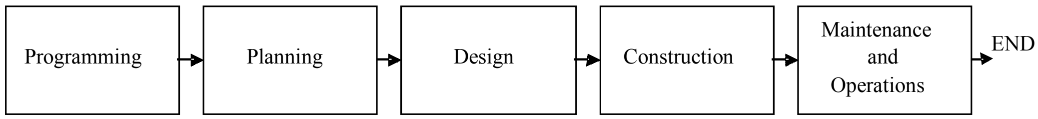


**FIGURE 1 Traditional transportation project delivery process.**

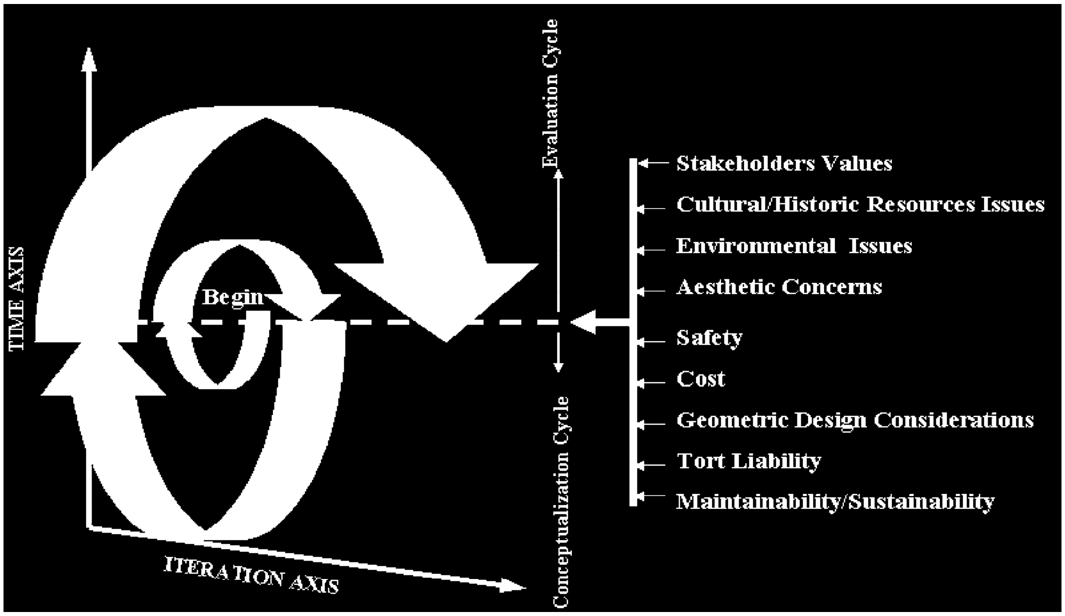


**FIGURE 2 CSD project delivery process**.

**FIGURE 3 Traffic island (SOURCE: Madison, Wisconsin, website).**

**FIGURE 4 Mortise-and-tenon barn (Source: FHWA).**

**FIGURE 5 Glenwood Canyon.**

RESEARCH NEEDS STATEMENTS

# Context-Sensitive Design, Including Aesthetics and Visual Quality

## 1. Quantification of Benefits and Cost-Effectiveness of Context-sensitive Design/Solutions in Transportation Facilities

### Problem Statement

There is a widely shared perception that involving stakeholders in the project development process results in solutions that recognize and meet environmental, geometric, and safety needs with a minimum of project delays and controversy with stakeholders. If this is the case, there are significant benefits that can be expressed in terms of cost savings. This proposal is an effort to quantify the overall value of using the "context-sensitive design/solutions" approach to the project planning and development process.

Evaluation of proposed transportation facilities has often been restricted to areas such as cost analysis, travel-time savings, emissions reductions, environmental impact analysis, etc. An abundance of data are produced in these studies. These data usually address a particular mode, such as transit or highways, and specific aspects that are easily quantified, such as ridership, noise increases, wetland impacts, arterial capacity, etc. Data on less readily quantifiable concerns, including cultural resources, community values, aesthetic preferences, and visual quality, is lacking. Consequently, there are frequent controversies that delay project delivery and significantly increase project costs.

The context-sensitive approach is a process that seeks to identify and integrate all transportation engineering concerns with cultural and community values, resulting in "context-sensitive solutions." To be effective, this process must begin in the planning phase and continue through programming, design development, and delivery of the final product.

The economic impacts of this process in terms of avoiding delays and unplanned costs have not been documented. A comprehensive analysis of the economic efficiency and other community benefits inherent in the early consideration of contextual influences in conjunction with transportation design parameters would be of great value to all participating parties (community, elected officials, MPOs, state departments of transportation, transit operators, etc.) in the development of regional transportation plans.

### Proposed Research

The goal of this research is to quantify the benefits of "context-sensitive design/solutions" in transportation facilities, including benefits that are easily quantifiable as well as those that are often considered nonquantifiable. This research will provide support for transportation investments and will provide guidelines and methods for communities to incorporate context-sensitive design/solutions into their planning, programming, and project development procedures. The research includes the following tasks:

1. Review of research relevant to the quantification of benefits of the context-sensitive solutions process;
2. Evaluation of the benefits of investments in context-sensitive solutions in selected projects; potentially quantifiable benefits include

- Expedited acceptance by stakeholders (pre-project delivery),
- Decreased delivery costs (time) due to stakeholder acceptance,
- Increased and improved opportunities for joint-use of the facility (e.g., bikeways parallel to highways), and
- Increased stakeholder satisfaction (post-project);

3. Evaluation of state and community willingness-to-pay for different types and degrees of investment in context-sensitive design/solutions;
4. Analysis of similarities and differences between regions; and
5. Development of guidelines for incorporating context-sensitive design/solutions into cost analyses.

**Cost:** $450,000
**Duration:** 24 months

## 2. Performance Measurement for Evaluating Stakeholder Satisfaction with Context-Sensitive Designs and Solutions

### Problem Statement

Traditional methods of measuring the success of transportation projects have focused on cost, schedule, capacity, mobility, and safety. These measures do *not* provide transportation agencies and transportation project managers with the information they need to assess the success of projects completed within the contemporary context-sensitive environment. Consequently, there are no definitive objective measures to support the institutionalization of context identification and definition as part of the transportation project planning, design, and implementation process.

The research is important for two reasons:

1. It will provide state transportation agencies with the tools they need in the project development processes to satisfactorily respect and acknowledge community goals and objectives.
2. It will give communities the tools and vocabulary required to articulate elements of project acceptance to other communities, local and state elected representatives, and other decision makers. This improves the credibility of the state transportation agency, thus enhancing public involvement and the progress of future projects and supporting funding allocation opportunities.

### Proposed Research

Performance measures will be developed to determine how well the completed project satisfies the purpose and need as agreed to by the full range of stakeholders. Examples of performance measures areas follows:

- The project is safe for both the user and the community,
- The project is in harmony with the community,
- The project meets or exceeds the expectations of both designer and stakeholder,
- The project achieves a level of excellence in people's minds,
- The project exhibits efficient and effective use of the resources of all the involved parties,
- The project was designed and built with minimal disruption to the community, and

- The project is described as having added value to the community.

The research will identify areas to be measured, including those cited above, and create a rational method to conduct the measurements. The performance measurement process will be piloted on a minimum of 10 projects in at least 6 states. The results of the pilot study shall be confirmed by a process to be proposed by the researcher and approved by the project panel.

**Cost:** $450,000
**Duration:** 36 months

### 3. Early and Continuous Scoping and Stakeholder Involvement

**Problem Statement**
Transportation projects are often planned and developed conceptually before public and stakeholder involvement activities are initiated. Many transportation agencies have not fully implemented and linked stakeholder involvement for context-sensitive design/solutions throughout the entire transportation system development process. Therefore, whereas the need for a project may be clearly articulated, the community values and context of the built and natural environment may not have received sufficient consideration. Consequently, projects must then be rescoped, causing schedule delays and budget revisions. Additionally, programmed elements that have been made without full stakeholder input often impose constraints that prevent designers from responding to community goals and values in a context-sensitive manner. Under these conditions, projects are either delayed, not completed, or result in stakeholder dissatisfaction.

**Proposed Research**
The goal of this research is to identify processes and tools to incorporate early and continuous scoping and stakeholder involvement that optimizes opportunities for context-sensitive design/solutions throughout the entire transportation system development process as follows:

- Identify traditional processes and practices common to many transportation agencies such as long-range planning, implementation planning, concept development, environmental analysis, design, construction, and maintenance that could be modified to incorporate early and continuous stakeholder involvement for successful context-sensitive design/solutions. Recommend the modifications.
- Identify improved or new processes that prompt and ensure successful communication among stakeholders, facilitate project scoping, and analyze the performance required to implement these practices.
- Identify cost-effective tools and methods to prompt and track stakeholder involvement and the context-sensitive design/solution commitments at all stages of transportation system development.

**Cost:** $400,000
**Duration:** 36 months

### 4. Best Practices for Effective Project Visualization

**Problem Statement**

"Context-Sensitive Design/Solutions" and project development rely on effective communication among the public, planners, and the project development team. The technical drawings and maps required to construct a transportation project are not always effective instruments for communicating with other nontechnical disciplines and the public. Communicating to the public what the project will look like and how it will operate are essential tools in developing meaningful and effective dialogue. Visualization technology has been recognized as an important tool in communication during the planning and design process. The technology applications include 2-D, 3-D, and 4-D presentation techniques. Some early attempts at using these technologies have inadvertently fostered public mistrust, whereas other efforts have been extremely successful.

The variation in cost and effectiveness of the wide variety of visualization tools available is not well understood. State and local transportation agencies would benefit from a study of visualization tools, their relative costs, and their effectiveness in facilitating transportation planning, project programming, and design.

**Proposed Research**

The objective of this project is to examine the palette of visualization tools and evaluate the relative effectiveness of each option in relation to specific communication needs. The proposed research is to survey visualization tools and techniques employed by project managers from the United States and other countries in the planning and project development processes.

The study should, to the extent possible, include successful and unsuccessful utilization of 2-D, 3-D, and 4-D representations, and model simulations. For each surveyed technique, the report should evaluate the effectiveness of each visualization technique. Values to be considered include

- Cost per unit,
- Stakeholder response and acceptance,
- Analysis of effective venues, and
- Recommended visualization tool selection process.

**Cost:** $375,000
**Duration:** 24 months

### 5. Tools to Identify and Define Project and Regional Context

**Problem Statement**

States and communities do not always possess the knowledge, organization, and expertise to identify and articulate the issues, needs, and desires that set the "contextual framework" in which a project or group of transportation projects will be undertaken. To contribute constructively to the transportation project development process, a community must first have a clear sense of its vision and goals. Furthermore, agency sponsors of transportation projects have a continuing responsibility to assure that the effects of the project on the landscape it traverses are identified, evaluated, and considered. The landscape refers to the built, natural, and social environment of a community. These elements contribute to the community's contextual identity, which also includes the community's vision and goals.

It is essential that the stakeholders understand the particular project, how it will be constructed, and how it will contribute to the realization of the community's vision and goals. It is equally important for the transportation agency to understand the contextual framework of the community. This proposal seeks to define and develop tools for the identification and articulation of community context.

**Proposed Research**

A succinct definition of context needs to be developed within the community in terms of its aesthetic character, visual quality, cultural diversity, and how these elements translate into the existing context.

The research will identify the various techniques currently employed by communities to articulate their goals and visions. The success of the techniques will be evaluated and recommendations developed for the use by communities. It is anticipated that the recommended techniques will include stakeholder identification and conflict resolution components. It should also identify partnerships, and may identify the role of municipal/regional planning organizations when the values of the served communities within the transportation corridor are clearly linked and can be individually stated. The following questions need to be answered:

1. How does a community define its context?
   - Existing context,
   - Future context,
   - Vocabulary to be used, or
   - Hierarchy of community attributes.
2. Who defines community context?
   - Public officials,
   - Organization representatives,
   - Neighborhood leaders, or
   - Men/women on the street.
3. When should community context be identified?
   - During land use transportation planning,
   - Transportation project planning, or
   - Project development process.

**Cost:** $400,000
**Duration:** 36 months

# Cultural Resources

## WORK GROUP PARTICIPANTS

### Panel Moderators

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RESOURCE PAPER

# Cultural Resources

Terry Klein, *SRI Foundation*
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Streamlining and stewardship are the two primary concepts shaping today's environmental and transportation programs, following the mandates of the 1998 Transportation Equity Act for the 21st Century (TEA-21). As a result, there is a need for more efficient and cost-effective means of performing environmental work, for new technologies, for new analytical tools and procedures, and for increasing partnerships among transportation and environmental specialists and a diverse public. The purpose of the third Transportation Environmental Research Needs Conference is to identify the research areas that would address these needs.

To identify the current and future research needs of historic preservation in transportation it is important to first review the results of the previous (1996) Environmental Research Needs Conference and examine the events and changes that have occurred in the practice since then.

The Resource Paper that guided the Cultural Resource work group at the 1996 conference highlighted several key issues. These issues were the result of discussions with and among transportation agencies, state historic preservation offices (SHPOs), the cultural resource consultant community, and the public, and included

- The need for better integration, synthesis, and dissemination of cultural resource information that has been collected for decades and continues to be collected;
- The need to develop computerized cultural resource databases to better manage and use this information;
- The improved use of this information for planning, management, scholarly research, and public education and enjoyment;
- Problems and inefficiencies that occur due to the variable interpretations of historic preservation and transportation laws and regulations from state to state and among agencies at the national level;
- Addressing the ambiguities and frustrations associated with defining project areas of potential effects, restriction of actions to project rights-of-way, and the lack of guidance on evaluating and treating linear historic resources;
- The need to develop mitigation programs that result in better preservation of important resources, are less costly, and provide a public benefit;
- The need for greater flexibility in mitigation measures, particularly in terms of historic bridges and other historic transportation facilities; and
- The need for the enhancement of public involvement and education.

Using these issues as a framework, the Cultural Resource work group identified the following six research needs statements:

- Review and improve the existing processes and procedures for evaluating cultural resource significance.

- Identify techniques to improve public/private dialogue regarding impacts and benefits of transportation projects on cultural resources.
- Explore how best to successfully incorporate 550 tribal nations in an existing transportation network, which recognizes the vale of culture and respects sovereign authority?
- Develop effects assessment guidance.
- Evaluate efficiency of “innovative” versus “standard” cultural resource mitigation.
- Identify and recommend roadway design considerations that can be modified and applied in specially designated corridors.

Of these six research needs, the first, involving the improvement of existing procedures for evaluating cultural resource significance, was ranked as the highest research priority.

In 1999, “A National Forum on Assessing Historic Significance for Transportation Programs” was held in Washington, D.C. Sponsored by the Transportation Research Board, the Federal Highway Administration (FHWA), and the National Park Service (NPS), this forum brought together over 190 experienced professionals working in many areas of historic preservation to identify critical issues in determining the significance of historic properties for transportation programs. Three recommendations were continually repeated during the multiple working group sessions at the forum:

1. New initiatives and funding strategies should be identified to develop regional and statewide historic contexts of mutual benefit to transportation agencies, SHPOs, Tribal Historic Preservation Officers (THPOs), and other interested agencies.
2. New and expanded funding sources must be identified and secured to improve the process of assessment of historic property significance.
3. Much broader dissemination of information on historic contexts must occur, with this information made available to agencies, consultants, SHPOs/THPOs, and the general public. The Internet was one tool suggested to meet this objective.

Also in 1999 (and again in 2000), the Advisory Council on Historic Preservation released the revised regulations implementing Section 106 of the National Historic Preservation Act (36 CFR 800). The most prominent changes and clarifications from the viewpoint of transportation programs were

- The role of federally recognized tribes in the Section 106 process, particularly in terms of consultation involving traditional cultural properties off tribal lands;
- The role of THPOs;
- The role of consulting parties throughout the Section 106 process;
- The removal of the “no adverse effect” determination for affects on archaeological resources that are of value only for the information that they contain;
- Guidance on the phasing of historic property identification and evaluation; and
- Guidance on the integration of Section 106 with the National Environmental Policy Act (NEPA) process.

The one change/clarification that has raised the greatest number of questions and concerns is the role of Native Americans in the consultation process. Transportation managers, historic preservation specialists, and tribes are asking such questions as: What is a good faith and reasonable effort in tribal consultation? When does consultation occur; how is do be done; and who should be involved? How do transportation managers deal with this often extensive and lengthy consultation process given the push to advance projects in an expedited manner? What does a "no response" from tribes mean and how should it be handled? How do the parties deal with conflicts that can result from this consultation process? How do tribes handle the ever-increasing number of requests for consultation given their limited staffing and financial resources? Some state departments of transportation (DOTs) and tribes have begun to address these and related issues by establishing clear guidance and procedures for consultation and, in some cases, establishing formal agreements on how consultation is to take place.

In November 2001, TRB and the National Cooperative Highway Research Program (NCHRP) funded the top research need identified by the Cultural Resource work group at the 1996 Research Needs Conference: the improvement of existing procedures for evaluating cultural resource significance, with a focus on the use of information technology. This study also considered the recommendations of the 1999 national significance forum. The first phase of the study involved the collection of information on how state DOTs and SHPOs use (or do not use) information technology in making decisions on resource significance. This was accomplished through extensive literature research and a survey questionnaire sent to all DOTs and SHPOs, in addition to THPOs and a selection of federal agencies. Both the survey and literature search examined whether or not these agencies maintained cultural resource inventories and historic contexts in electronic formats, and if these inventories and historic contexts (either in paper or electronic forms) were used in significance evaluations.

The key findings of the NCHRP study were as follows:

- Most SHPOs and DOTs have not completed a standard set of historic contexts for their states and, if the contexts exist, they exist only on paper.
- Many SHPOs and DOTs do not have their resource inventories in a computer database.
- There are competing state, regional, and national efforts in terms of computerized cultural resource database development.
- When databases do exist, they are not developed for use as a tool for evaluating significance.Instead, the majority is used to describe and locate resources on the landscape regardless of whether or not they are listed in or eligible for listing in the National Register.
- The majority of the DOT and SHPO staffs rarely use their cultural resource inventories or historic contexts to evaluate cultural resources.Instead, they rely on their own personal experiences and knowledge, and those of their cultural resource consultants.
- DOT and SHPO staff are generally not satisfied with the tools that they have to make and justify their decisions on resource significance, and would like to see increased sharing of information and approaches among agencies and states.

The NCHRP study then made recommendations to improve the current resource evaluation process used by SHPOs, DOTs, and other agencies. The next step in the study is for the NCHRP to evaluate the recommended improvement options and possibly implement an option(s) through a pilot study, involving select states and/or agencies.

The NCHRP study's findings, the 1999 significance forum, changes and clarifications in the most recent version of 36 CFR 800, and the issues discussed during the previous Research Needs Conference can all serve as the foundation for identifying the important cultural resource/transportation research needs of 2002 and beyond. It is also recommended that definition of these important research needs be considered in the context of the two concepts currently guiding transportation programs in the United States; streamlining and environmental stewardship.

The sections of TEA-21 addressing environmental streamlining call for the reduction and elimination of delays and unnecessary duplication in current environmental procedures. Streamlining also calls for earlier and more efficient coordination among agencies involved in the environmental decision-making process to reduce conflicts and delays. Furthermore, DOT Secretary Norman Mineta noted in his recent testimony before the Senate Environment and Public Works Committee that the core principals and values of future transportation programs include "developing the data and analyses critical to sound transportation decision making," and "focusing more on the management and performance of the system as a whole rather than on 'inputs' or functional components such as planning, development, construction, operation, and maintenance themselves" (*1*).

During a workshop on environmental stewardship held at the TRB 2002 annual meeting in Washington, D.C., John Carr of the Kentucky Transportation Cabinet noted that "environmental streamlining for transportation projects cannot happen without environmental stewardship" (*1*). The purpose of this workshop was to address the next steps in implementing environmental stewardship for transportation programs. The working session of the workshop developed "working documents" that identified environmental stewardship opportunities for planning, design, construction, maintenance, and operations. The following is a sample of the "opportunities" that have relevance to historic preservation issues:

- Establish broad community contexts for transportation programs, plans, and projects—cultural, social, ecological, watershed, etc.
- Plan for environmental quality and stewardship, not just regulatory conformity and compliance.
- Identify, balance, integrate, and document regional transportation and environmental goals, plans, and purpose and need.
- Identify and consider environmental issues important to advocacy/community organizations.
- Plan for stewardship of historic transportation infrastructure.
- Implement matched funding opportunities with other agencies for transportation/environmental stewardship initiatives.
- Start mitigation in the planning phase when environmental concerns are identified early.
- Consider the impact of system/project planning on minority and tribal communities.
- Educate communities about the planning process and conduct a strategic evaluation of potential needs of the communities, integrating all partners in the planning process.
- Use context-sensitive design.
- Go beyond the "environmental mitigation" paradigm. Replace it with well-integrated environmentally sensitive design concepts and multi-objective design concepts, as agreed to by the full range of stakeholders.
- Define community, transportation, and environmental context and performance measures before design.

As part of this national focus on environmental streamlining, there has been increasing attention on the perceived overlap of the mandates of Section 106 of the National Historic

Preservation Act and Section 4(f) of the Department of Transportation Act. For example, the American Association of State Highway and Transportation Officials' (AASHTO) comments on FHWA's proposed NEPA and Section 4(f) regulations issued on May 25, 2000, raised several concerns about Section 4(f). In their comments (U.S. DOT Docket No. 99-5989), AASHTO states that the current interpretation of 4(f) results in the protection of properties of questionable significance and forces the DOTs and FHWA to elevate the protection of National Register listed and eligible properties [and other 4(f) properties] over other environmental, economic, and social factors during transportation decision making. AASHTO questions current approaches to 4(f) that seem to ignore a common sense approach where different types of "uses" should be treated differently. AASHTO goes on to recommend, that because most historic properties that fall under the Section 106 process are also protected under Section 4(f), that the completion of the Section 106 process should be used to establish compliance with Section 4(f).

Throughout 2001, the FHWA held several Section 4(f) streamlining meetings across the country, which were attended by FHWA and state DOT staff. The purpose of the meetings was to discuss legitimate flexibility currently available under Section 4(f) and to examine ways of streamlining the Section 4(f) process. During the "brainstorming" components of the meetings, the participants offered a wide range of recommendations to address the "Section 4(f) problem," including revising the current FHWA Section 4(f) policy paper to include stronger discussions on balancing resources and flexibility in applying the law; interpreting a Section 106 finding of "no adverse effect" as "no use"; recognizing different levels of "historic significance"; restricting the application of Section 4(f) to historic properties that will be preserved; and even removing "historic properties" from Section 4(f).

Another streamlining-related issue in historic preservation involves the national Interstate highway system. The Eisenhower Interstate Highways are approaching the age where they could be considered eligible for listing in the National Register of Historic Places. Rather than having the system's eligibility evaluated in a piecemeal fashion within individual states, a more systematic approach has begun at the national level, using a combined national and state perspective. These discussions are assessing the historic significance of the different components of the system and the effect that a National Register designation of the system or its parts would have on the operation of the Interstate highways, in terms of planning, maintenance, upgrades, and other required improvements.

There are several themes and issues that are repeated throughout these different forums, meetings, conferences, and national discussions on streamlining and stewardship and on historic preservation in transportation including

- Better access, analysis, and use of data for making sound transportation decisions.
- Early and more efficient coordination among all parties involved in all stages and components of transportation programs.
- Early and more efficient coordination and integration of overlapping and at times conflicting regulatory requirements and agency procedures.
- The need for contextual information—for evaluating resource significance, determining what the "context" is in context-sensitive design, and for defining and meeting local and regional historic preservation goals, plans, and purpose and need.
- The need to obtain constructive public input in the creation and use of this contextual information. Tribal and minority communities need to be partners in this effort.

- A definition of clear principals and procedures for the role of tribes in the Section 106 process.
- The conducting of historic preservation actions that have a direct and tangible public benefit.
- Looking for and developing creative funding mechanisms to meet tribal and community preservation goals, in tandem with local and regional transportation needs.
- Developing and implementing greater flexibility in the implementation of Section 106, Section 4(f), and NEPA; addressing overlapping procedures and processes using creative and innovative approaches.

All of these themes and issues, and the range of possible actions that would address them, require a shift in how transportation and historic preservation professionals normally operate. The focus on project-specific issues has to be lessened, and there needs to be more attention given to strategic planning and actions that would streamline future projects and enhance stewardship. Also, specific projects need to be observed in a new light—as opportunities to test, implement, and expand on these issues in creative and innovate ways.

## References

1. BNA, Inc. *Transportation/Environment Alert*. Vol. 4, Issue 20, Jan. 25, 2002.

RESEARCH NEEDS STATEMENTS

# Cultural Resources

### 1. Streamlining the Evaluation of Cultural Resources by Using Historic Contexts

**Problem Statement**
Transportation agencies spend substantial funds to identify cultural resources that are eligible for the National Register of Historic Places and thus subject to environmental regulations. Despite the fact that the National Register policy calls for the use of historic contexts when determining eligibility of identified resources, recent nationwide survey findings reveal that eligibility decisions are most often determined on a piecemeal basis and without the benefit of comparison with like resources. In 1999, the TRB-sponsored "National Forum on Assessing Historic Significance for Transportation Programs" identified the lack of historic contexts as the biggest problem in assessing significance.

When used, historic contexts have proven to be an effective and efficient tool in streamlining the evaluation process and in facilitating good decision making. They need to be applied more often to resource types commonly encountered in transportation projects—resources that are individually considered time and again such as bridges, rural landscapes, farmsteads, post-World War II subdivisions, standard design houses, lithic scatters, roads, and railroads. Everything has history; a historic context identifies what of that history is significant within the resource type. Their use eliminates inconsistency and confusion over eligibility and expedites the environmental review and scoping processes. It efficiently identifies what is significant and eligible while eliminating consideration of the great number of resources that are not eligible. An historic context also promotes good stewardship of cultural resources by identifying those that are worthy of preservation before they become part of a project.

**Proposed Research**
A critical evaluation of the preparation and application of historic contexts will be undertaken. The initial step will be to conduct a nationwide survey of state historic preservation offices (SHPOs) and departments of transportation (DOTs). The survey data will be synthesized to address the following issues:

- Assessment/investigation of why historic contexts are not widely used.
- Analysis/synthesis of the cost benefit of evaluating resources using historic contexts.
- Identification of methodologies and approaches that have proven to be successful.
- Development of guidance for the preparation and application of historic contexts. The guidance will emphasize what a historic context must accomplish and how it is completed.
- Development of a shared national database on historic contexts that can include a shelf list of completed contexts and their location to ensure easy, widespread dissemination of existing and newly generated data.
- Identification of funding sources and agency/organizations to prepare contexts.
- Development and implementation of a mechanism to disseminate the findings and recommendations through workshops. Those participating would be the stakeholders including

at a minimum, SHPOs, THPOs, DOTs, NPS, the U.S. Army Corps of Engineers, and consultants.

**Cost:** $350,000
**Duration:** 12–18 months

### 2. Evaluating Historic Significance of the Interstate Highway System: Developing an Historic Context

**Problem Statement**
In 2000, the Missouri SHPO stated that all Interstate Highways within Missouri and their constituent components (i.e., bridges), regardless of their integrity, were eligible for the National Register of Historic Places (NRHP). This opinion was offered in the absence of an historical context or inventory. Because Interstate Highways are a national system comprised of individual structures, the scope of this opinion is far reaching. To continue to serve its intended transportation functions, the Interstate system will have to evolve through the construction of new facilities such as ramps, overpasses, new lanes, and, in many cases, the addition of multimodal facilities. Nationwide, every state is modifying the existing Interstate system and currently is or soon will be grappling with the question of NRHP eligibility as portions of the Interstate within each state reach 50 years of age. There is a consensus on the importance of the Interstate's role in American history, but not whether the Interstate system meets the criteria for NRHP eligibility. If the Missouri SHPO's opinion that the Interstate system is NRHP eligible stands, it raises a number of critical issues concerning compliance with Section 106 and Section 4(f) regulations for future projects involving modification to the interstate, not the least of which is adding expensive project delays and increased costs to badly needed improvements. Preparation of a national level historic context for the Interstate system is needed. This context should address the definition of the Interstate "system" and its boundaries, preparation of a context for evaluating the system's historical significance, evaluation of the integrity of the system, and evaluation of the Interstate system's eligibility to the NRHP.

**Proposed Research**
This proposal calls for the development of an historical context for the NRHP eligibility evaluation of the Interstate system. Specific components of this context should include:

- Identification and definition of just what is considered to be the "national interstate highway system";
- Evaluation of the integrity, periods of significance, and areas of significance of the Interstate system and its components;
- Preparation of an evaluation of NRHP eligibility of the Interstate system as a whole or any constituent segment determined to be NRHP eligible; and
- Recommended programmatic approaches to assessing and addressing effects to the system if this research recommends that all or parts of the Interstate system is NRHP eligible.

**Cost:** $350,000
**Duration:** 18 months

## 3. Rethinking the Application, Effectiveness, Scope, and Flexibility of Section 4(f) as Applied to Historic Properties

### Problem Statement

The enactment of the 1966 Department of Transportation Act's Section 4(f) was intended to preserve historic properties as well as other Section 4(f) resources. Its application however has resulted in a lengthy process that too often results in "preservation" with regard only to particular project impacts and not future impacts. The worthy goal of preservation is often short lived because historic properties, unlike other Section 4(f) protected resources, do not have to be in public ownership, and long-term preservation is not assured. The definition of an eligible historic property subject to Section 4(f) is extremely broad, capturing properties of esoteric local importance as well as those of national importance, and creating a large volume of properties subject to Section 4(f) consideration. Section 4(f) influences project planning without resulting in historic preservation regardless of the effect determination under Section 106. Thus, the current application of the Section 4(f) process inhibits the goals of streamlining and stewardship, sometimes at considerable expense.

Any effort to streamline the Section 4(f) process and improve its capacity for promoting stewardship would involve rethinking the 1987 policy guidance and making recommendations for regulatory or statutory changes. Possible questions to be addressed include could the definition of an historic property protected under Section 4(f) be narrowed? and could Section 4(f) be applied differently to privately owned properties? There is a high standard for the evaluation of whether an alternative is both prudent and feasible that the courts have inconsistently applied. Could the significance (high, medium, low or local level, state level, and national level) of a property influence whether an alternative should be considered prudent and feasible? Could there be flexibility in the application of Section 4(f) when the historic property (that is not a transportation facility) is not adversely affected under Section 106? Could there be flexibility in the concept of “use” regarding the significance of a property and whether a property would be “preserved in place?”

### Proposed Research

1. Compile and synthesize documentation of current practice in the application of Section 4(f) by state DOT environmental planning offices and the FHWA/FTA state and regional offices. This would include collecting information on current procedures (beyond the 1987 guidance) followed to comply with Section 4(f). Also, what historic Section 4(f) properties have been identified? What are the time frames for completing Section 4(f)? Have streamlining procedures been applied and in what ways? What is the result of the avoidance of Section 4(f) historic properties after at least 1 year? What are the costs associated with avoidance? How is the concept of prudent and feasible avoidance alternatives applied?
2. Compile and synthesize documentation on current guidance, rules, policy papers, and case law on the application of Section 4(f) to historic properties.
3. Review the synthesized documentation and evaluate and compare the current practices with the existing guidance. The results of the evaluation will be compiled into a report providing recommendations for changes in guidelines, regulation, and possibly legislation. Rethinking the 1987 guidelines would result in new guidelines and their implementation. Some changes could only be implemented by revisions to regulation, and still others would require legislative change. These recommendations would, at a minimum

- Identify flexibility in the application of Section 4(f) as it applies to the level of significance of historic properties.
- Make recommendations that would streamline compliance with Section 4(f).
- Identify flexibility in the application of Section 4(f) in the evaluation of effects of a project on a historic property.
- Identify flexibility in the application of the concept of "prudent and feasible."
- Make recommendations for preservation measures other than avoidance that would be in compliance with Section 4(f).

**Cost:** $300,000
**Duration:** 18–24 months

### 4. Streamlining the Tribal Consultation Process

**Problem Statement**
Numerous federal laws and directives require federal, state, and local transportation agencies to consult with federally recognized tribal governments in historic and cultural preservation and planning processes. Tribes consult in their capacity as sovereign governments, as members of the public, and as cooperating agencies under NEPA. These requirements include TEA-21 and the federal regulations for implementing Section 106 of the National Historic Preservation Act. The scope of consultation can be minimal, as in cases where the tribe claims no interest in a project, to all encompassing concerns in a project area.

State DOTs recently identified Native American consultation as one of the most challenging components of their program. Federal and state transportation agencies and tribes have a broad disparity in administrative capacity to effectively participate in the various consultation activities required under current laws and executive orders. This disparity is further compounded because states have many tribes claiming historic interest in areas impacted by proposed transportation projects. Currently there are over 550 federally recognized tribal governments in the continental United States and Alaska. Many state agencies must consult with tribes no longer physically present in the state. For tribes, the scope of consultation demands is equally difficult. Tribes often occupy land in more than one state and claim historic interest or occupancy in many states. Many are still in the process of documenting the historic areas they inhabited and the cultural information required to identify those areas.

The requirement for consultation between tribal, federal, state, and local agencies emerged from various sources without clear directives or definitions. No training or technology transfer programs that specifically focus on tribal consultation during the transportation project development process are available for any consulting party. Programs for efficiently identifying the appropriate tribal governments for consultation are in their infancy and many important research questions remain unanswered. The potential exists for rapid improvement in this area of consultation.

**Proposed Research**
Researchers will have responsibility for completing the following five principal tasks:

1. Conduct a survey to determine effectiveness of existing consultation practices and develop a more inclusive definition of the problems from the perspective of the transportation agencies and the tribal governments.
2. Determine technical assistance needs of the transportation agencies and tribal governments.
3. Develop a best practices manual and training program for consulting parties that would lead to a peer-to-peer consulting relationship.
4. Identify streamlining opportunities that incorporate various laws and executive orders that require tribal consultation.
5. Identify funding needs and mechanisms to enhance tribal government participation in the consultation process.

**Cost:** $400,000
**Duration:** 18 months

## 5. Best Practice and Guidance for Historic Preservation Stewardship and Streamlining

### Problem Statement

Environmental stewardship is a key mandate of TEA-21 and is supported by the National Historic Preservation Act and NEPA. Transportation agencies (federal and state DOTs) conduct more cultural resource studies and expend more funds in compliance with historic preservation law than other federal and state agencies. The DOTs are quite successful in avoiding impacts to historic properties and have developed strategies to minimize the impacts projects have on the historic landscape. Unfortunately, avoidance does not equate with preservation.

Historic preservation is not a common byproduct of project development. When it occurs, it is usually limited to structures on the transportation system, such as the rehabilitation of historic bridges. Even archaeological sites that are "preserved" through data recovery are still lost to future researchers. Avoided historic properties may be and often are affected or destroyed by other public and private development. After the project is completed and the effort to meet federal and state laws has been accomplished, what in fact is left? What are the ways that DOTs can be more successful in preserving historic resources, while still working within the agency's mission of an efficient and safe transportation system?

### Proposed Research

1. Explore programmatic approaches to historic preservation that may be established during the pre-project, planning process. Examples include historic corridor preservation, bridge management plans where preservation is an integral component, and early identification of individually significant resources or classes of resources to be targeted for preservation. Survey DOTs and metropolitan planning organizations and land development departments for instances where historic preservation management plans have been used to influence transportation planning decisions.
2. Survey DOTs, SHPOs, and federal agencies (as appropriate) for examples where future preservation of an historic property has been secured as a result of a project or program. What has been effective and what has not?

3. Consult with natural resource agencies to identify models for historic preservation from their resource conservation efforts, such as resource banking and public/private partnerships.
4. Conduct an economic analysis of programmatic approaches that balance targeted historic preservation with streamlined process.
5. Analyze FHWA regulations and policy that can promote active historic preservation and identify any barriers from existing legislation or regulation.
6. Explore techniques for long-term preservation of resources that are not immediately affected by a project, but could be affected at a later date from regional growth and development.

Compile these examples into a best practices report and disseminate through the FHWA web and TRB publication.

**Cost:** $300,000
**Duration:** 18 months

### 6. TRIBAL TRANSPORTATION ORGANIZATIONAL DEVELOPMENT MODELS

**Problem Statement**

Tribal governments are currently struggling to develop the organizational capacity to meet the increasing requirements for intergovernmental coordination relating to transportation program development.

The Indian Reservation Road Program has been in existence since 1940 and has been administered by the U.S. Department of the Interior and the FHWA for the benefit of tribal governments. Since the passage of the Indian Self-Determination and Education Assistance Act of 1978, tribal governments have the opportunity to assume operation of most aspects of the Bureau of Indian Affair's transportation programs. Support for tribal participation in the operation of transportation programs serving tribal lands and communities was further strengthened by the passage of both ISTEA and TEA-21.

In addition, various federal laws and presidential executive orders require tribal consultation in Federal-Aid highway projects and other projects expending federal funds. These federal mandates include Section 106 of the Historic Preservation Act of 1966 (as amended), Section 4(f) of the United States Department of Transportation Act of 1966, and the Native American Graves Protection and Repatriation Act of 1989.

This relatively recent emergence as a principal and/or consulting transportation agency has many unique administrative challenges that can frustrate and delay ongoing tribal, federal, and state transportation projects and processes. No prior research has been undertaken to identify and quantify the challenges faced by tribes in administering transportation responsibilities and participating in multi-jurisdictional transportation projects.

An assessment of tribal organizational structures, functions, and administrative capacity would

- Clarify the level of current demand on tribal transportation staffs,
- Provide models of potential reorganization strategies to increase staff effectiveness, and
- Develop implementation plans for staff development and/or consultant procurement programs.

**Proposed Research**

This proposal calls for a study of transportation responsibilities and functions undertaken by tribal governments by virtue of their sovereign authority and through federal laws, regulations, and executive orders.

The research would identify the level of transportation activities occurring in small, medium, and large tribal agencies; develop effective organizational strategies for internalizing these functions within a tribal structure; identify funding levels necessary to support the various strategies; and identify opportunities for streamlining tribal transportation operations affecting internal tribal and external federal, state, and local transportation processes and projects. Key elements of this research are as follows:

1. Organize and lead an interdisciplinary research team to conduct a survey of existing tribal transportation organizations to identify existing program limitations, and suggest potential models for institutional reorganization. It is anticipated that such a team would have expertise in Native American issues, transportation, program management, organizational development, local economic development, and governance.
2. The team would conduct a survey of existing tribal transportation organizations, selected to provide a range tribal group size, effective land area, geographic distribution, and transportation system.
3. As part of this survey process, the team would identify and analyze examples of successful existing or past programs.
4. From the collected data, the team would develop a set of model organizational structures appropriate for tribal transportation agencies of various sizes and levels of transportation program requirements.
5. These models would be compiled into a Tribal Transportation Agency Organization Manual to provide guidance to the local groups on potential steps they might take to optimize the administrative capacity of their organization and staff. This manual would be used to develop an agency training program to provide on-site training to interested agency staffs.
6. The manual/training program will be used by tribes to identify staffing and operational support requirements best suited to their specific requirements and to develop implementation plans that could be used to guide staff development and/or consultant procurements programs.

**Cost** $400,000
**Duration:** 24 months

# Energy and Alternative Fuels

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RESOURCE PAPER

# Energy and Alternative Fuels

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The vitality and economic growth of the United States is linked to affordable transportation. In comparison to most countries, the United States is sparsely populated and development is pursued assuming access to transportation. This primarily involves highways, but also includes rail lines, airports, and marine terminals. The interstate highway system made large-scale freight movement possible by truck and facilitated the ability of everyone to see the country by car. The availability of good roads and inexpensive fuel resulted in the development of large cars without much regard for fuel efficiency. The decade of the 1960s was one of the most productive in U.S. history, due in part to a thriving automotive industry and inexpensive petroleum fuels. This situation came to a rapid end in 1974 when the Organization of Petroleum Exporting Countries (OPEC) dramatically raised the price of crude oil. The resulting increase in fuel prices in the United States caused auto sales to decline and induced a long period of slow growth and higher inflation.

Since the petroleum market adjustments of the 1970s, the inflation-adjusted price of crude oil has generally declined. However, beginning in the spring of 2000 prices increased because of increased market share and renewed resolve by OPEC and some non-OPEC members to control crude oil supply to raise prices.

Since the 1970s, several events combined to keep oil prices low: the end of the Cold War; a diminution in the market power of OPEC due to an increase in petroleum production from non-OPEC nations, and the cementing of U.S. security ties to the most important oil-exporting nations. Unfortunately, these developments have created complacency on the part of the American public not unlike that which preceded previous oil markets. The growing dependence of the United States on imported petroleum offsets the positive developments that have occurred in the global petroleum market over the past 20 years; that is, the potential impact of a petroleum market adjustment on the United States is increasing regardless of its origin or whether it is politically motivated. Historically, periods of low prices have been followed by steep price spikes, of which we have just recently been reminded.

In 2001, the terrorist attacks on the United States highlighted the political and cultural turmoil that exists in many of the countries on which we depend for much of our petroleum fuel. Unlike other energy using sectors, which have introduced substitute fuels and fuel switching flexibility since the market adjustments of the 1970s and 1980s, the transportation sector remains overwhelmingly dependent on petroleum-based fuels (approximately 2.5% of our liquid petroleum fuels are oxygenates) and on technologies that provide virtually no flexibility. The transportation sector currently accounts for approximately two-thirds of all U.S. petroleum use and roughly one-fourth of total U.S. energy consumption. Substitution of petroleum-based transportation fuels (gasoline and diesel) by nonpetroleum-based fuels (alternative fuels such as electricity, ethanol, hydrogen, liquefied petroleum gas, methanol, and natural gas) could be a key means of reducing the vulnerability of the U.S. transportation sector to future disruptions of petroleum supply.

## TRANSPORTATION ENERGY TRENDS

Since 1998, more than half of the petroleum the U.S. economy requires has been supplied by imports. The almost relentless increasing share of imports is due partly to the steady growth in transportation fuel demand, but a crucial cause is the depletion of domestic oil reserves. Whereas world oil production has yet to peak, domestic production has been in decline almost continuously since 1970. Domestic oil production now stands at 5.9 million barrels per day (mbpd), well below the peak of 9.6 mbpd in 1970. As illustrated in Figure 1, declining domestic production has created a gap between the oil demands of transportation and domestic supply. This gap is projected to roughly double by 2020 as domestic resources continue to decline and demand continues to grow. Oil imports amounted to $60 billion in 1999, equal to 18% of the U.S. trade deficit. For the first 6 months of 2000, oil imports were 26% of the trade deficit.

If the gap between the world's remaining oil and the demand for transportation energy is to be filled, then many new energy sources will be needed. Other hydrocarbon resources, including liquid fuels made from natural gas, coal, or tar sands, could fill this gap. Part, or perhaps even the entire gap, could be filled with more efficient vehicles and the use of alternative fuels such as natural gas, renewables (e.g., ethanol or biodiesel), or hydrogen derived from a combination of feedstocks. These alternatives have a range of energy, environmental (e.g., greenhouse gas emissions), and economic consequences.

Figure 2 shows the Energy Information Administration’s latest forecast of transportation energy demand to 2020. Jet fuel demand is projected to grow 2.5% annually due to inexpensive prices that encourage air travel. Diesel fuel demand is projected to grow 2.4% annually because of increased freight movement and the application of diesel engines in light-duty vehicles. Gasoline demand is projected to grow more modestly at 1.6% annually. These increases in demand are projected in spite of improvements in vehicle fuel economy and aircraft efficiency. This is because the demand for transportation continues to increase faster than efficiency improvements.

Outside the United States, transportation fuel demand is projected to grow even faster because of the rapid development of transportation systems and personal vehicles in many less developed countries. Their demand for petroleum fuels will rapidly become a significant market force and accelerate the day when crude oil production peaks and petroleum fuels become increasingly more costly.

## POTENTIAL FOR ALTERNATIVE FUELS IN TRANSPORTATION

The focus of alternative fuel implementation is primarily on highway vehicles. Aircraft, rail, and marine transportation modes all use large amounts of fuel, but their power plants are less amenable to using alternative fuels and the fuel they use (petroleum distillates) are less expensive than highway vehicle fuel, which makes the economic case for switching less compelling. In the long run, these applications will need new sources fuels as well. However, this paper focuses on highway alternative transportation fuels.

Alternative fuels are broadly defined as any fuels that are derived from crude oil. It is generally agreed that the primary alternative highway transportation fuels include ethanol, methanol, natural gas, propane, biodiesel, hydrogen, electricity, and liquid fuels derived from natural gas, generically known as “gas-to-liquids” or GTL.

### Alternative Fuel Use in the United States

Alternative fuel use in the United States has grown significantly during the past decade, as illustrated in Table 1. In 1992 (the first year data are available), alternative fuel use in the United States amounted to 229 million gasoline gallon equivalents; in 2001, alternative fuel use was estimated to be 366 million gasoline gallon equivalents, an overall increase of 60%.

As Table 1 shows, all of the alternative fuels have seen notable increases in use between 1992 and 2001, with the exception of methanol (neat and in M85) and ethanol in an E95 blend. The rise in compressed natural gas (CNG) and liquefied natural gas (LNG) usage is the result of an increasing number of CNG and LNG vehicles available from original equipment manufacturers. A large increase in ethanol (in the form of E85) has also occurred, because of an increased interest in E85 spurred by the large numbers of E85 flexible-fuel vehicles being produced by American manufacturers. Electricity has also enjoyed a large increase, due in part to the increasing availability of electric vehicles.

Methanol and E95 use experienced a decline between 1992 and 2001. Methanol use in a blend of 15% gasoline (known as M85) is declining because M85 vehicles have not been offered for sale since the early 1990s. The large decrease in neat methanol use can be attributed to neat methanol's popularity as a transit bus fuel in the early 1990s and the phase-out of these vehicles within the last 4 or 5 years. The small amount of E95 (ethanol blended with 5% gasoline) can be attributed to a small fleet of transit buses; it is presently thought not likely that use will increase in the coming years.

## Pollution and Air Quality Impacts of Alternative Fuels

### *Natural Gas*

Natural gas vehicles are capable of low gaseous exhaust emissions, depending on the emission controls employed. They also have no evaporative emissions or running loss emissions caused by the fuel, which does occur with gasoline and diesel vehicles. When used in heavy-duty vehicles to replace diesel engines, natural gas results in lower particulate matter (PM) emissions (by up to 90%), lower oxides of nitrogen ($NO_{x;}$ by about half), lower emissions of air toxics, and lower numbers of ultra-fine particles (typically by an order of magnitude). Using natural gas results in lower greenhouse gases (GHGs) by 10 to 25% for light-duty vehicles with smaller decreases for heavy-duty vehicles, because heavy-duty natural gas engines are less efficient than their diesel counterparts. Advanced natural gas engine technology, such as high-pressure direct injection, could further reduce GHG emissions from natural gas vehicles.

### *Propane*

Like natural gas, propane vehicles do not have evaporative or running loss emissions and they are capable of very low carbon monoxide and hydrocarbon emissions. Emissions of $NO_x$ are not significantly different from vehicles using gasoline. When used in heavy-duty vehicles to replace diesel engines, propane has emissions benefits similar to natural gas. Using propane results in GHG reductions of 10 to 25% for light-duty vehicles, with a smaller decrease for heavy-duty vehicles.

### *Methanol*

Methanol used in internal combustion engines has the potential for reduced $NO_x$ emissions and reduced emissions of ozone-forming pollutants. When used in a fuel cell, methanol will have zero emissions (direct methanol fuel cells) or can provide near-zero vehicle emissions (Proton

Exchange Membrane fuel cells with methanol reformers). Methanol production from natural gas (the preferred process) is quite clean, but GHG emissions compared with gasoline are unchanged or increased slightly when the methanol is used in flexible fuel vehicles. GHG reductions of approximately 50% are possible when the methanol is used in fuel cell vehicles.

***Ethanol***
Emissions from ethanol vehicles are not significantly different from their gasoline counterparts; however, the reactivity of these emissions (relative to ozone formation) is lower than for conventional gasoline. Ethanol can also be used in fuel cell vehicles (in neat form) where its emissions will be near zero. It is produced by means of fermentation of crops and can result in up to a 25% reduction in GHGs, whereas ethanol production from cellulose could result in net zero GHGs.

***Electricity***
Battery-electric vehicles have no tailpipe emissions of pollutants, but there are emissions associated with the generation of the electricity for battery recharging. Overall, emissions from electric vehicles can be much less than those from gasoline vehicles, depending on the power generation mix in use for the area where the vehicle is recharged. Electric vehicles using electricity produced from natural gas in combined cycle plants should result in reductions in GHGs of 60 to 70%.

***Biodiesel***
The use of biodiesel in conventional compression ignition engines can result in substantial reductions of emissions of hydrocarbons, carbon monoxide, and PM. Emissions of $NO_x$ and numbers of ultrafine PM are not significantly changed. GHGs from the use of biodiesel are reduced by approximately 65%; for example, using B20 would result in a reduction in GHGs of approximately 13% relative to conventional diesel fuel.

***Hydrogen***
All of the major auto manufacturers are working on fuel cell vehicles that use hydrogen to generate electricity. When hydrogen is oxidized in fuel cells, the only emission is water vapor. The only current practical and cost-effective source of energy to produce hydrogen in large quantities for transportation use appears to be from natural gas. Research is underway to develop novel, nonpolluting means of hydrogen production, including thermochemical water splitting, photolysis, and biological and photo-biological water splitting. Research is also underway to produce hydrogen from coal, using carbon sequestration. Fuel cell vehicles using hydrogen produced from natural gas should see reductions in GHGs by approximately 60%. Hydrogen produced from electrolysis of water using wind, nuclear, or hydropower will generate no GHGs. Other research is underway to develop small reformers that would be on-board vehicles and generate hydrogen on demand from virtually any liquid fuels. If successful, this offers the potential for the use of the existing liquid fuel infrastructure as fuel cell vehicles come to market.

***Gas-to-Liquid Fuels***
GTL fuels have been shown to primarily reduce emissions of PM and $NO_x$ from existing diesel vehicles by approximately 20%. Emissions of toxics should also be reduced compared with conventional diesel fuel, although definitive testing is incomplete. (These observations should

be considered preliminary because commercial GTL fuels are not currently available in the United States.) Vehicles using GTL fuels will have GHGs increased by approximately 10% compared with conventional diesel fuel.

**Alternative Fuel Legislation—Alternative Motor Fuels Act and the Energy Policy Act**
In response to growing concerns about oil dependency and air quality, Congress passed the Alternative Motor Fuels Act of 1988, establishing expanded research and development efforts, providing incentives, and establishing the first large-scale federal demonstration and evaluation of alternative fuel vehicles (AFVs). The federal government fleet was identified as a potential first user of AFVs. At this time, deployment strategies emphasized the need to develop, demonstrate, and evaluate the new alternative fuel technologies such as methanol, natural gas, and electric vehicles. Highly technical information was to be shared with auto companies, engineers, and early adopting fleets to speed development and provide real world testing data.

During the early 1990s, emphasis on AFVs increased. The Clean Air Act of 1990 established the Clean Fuel Fleet program, which was designed to promote the expanded use of clean AFVs in major metropolitan areas. In 1991, President Bush issued Executive Order 12759 requiring federal agencies to begin acquiring AFVs in large numbers, and launched the development of the National Energy Strategy. With passage of the Energy Policy Act of 1992 (EPACT), shortly after the successful conclusion of the Iraqi war, Congress codified and expanded these earlier efforts.

Importantly, EPACT required selected fleets to lead the acquisition of AFVs to establish a more certain market for manufacturers of light-duty vehicles. Beginning in 1993, federal fleets, state fleets, and fuel providers were required to buy increasing numbers of light-duty AFVs. The EPACT goals are to replace 10% of motor fuel use in 2000 and 30% by 2010 with alternative fuels or replacement fuels (nonpetroleum components of conventional fuels).

Several assumptions guided the authors of EPACT, but many of them turned out to be wrong; for example

- It was widely believed at the time that market barriers to alternative fuels were primarily informational, that information development and dissemination would induce significant consumer demand.
- It was assumed that the light-duty vehicle mandates would solve the so-called "chicken and egg" problem by creating a demand for the construction of refueling stations. This was proved wrong when fleets operating dual-fuel vehicles opted to use gasoline almost 100% of the time.
- It was also assumed that fleets are uniform, centrally refueled, buy mostly the same type of vehicles, and are easily regulated. These assumptions were all wrong.

The small grants and incentives provided in the EPACT were assumed to be sufficient to grow the market. Unfortunately, the incentives were never sufficient to overcome the incremental cost of the vehicles and the inconvenience associated with refueling. Perhaps most significantly, however, EPACT never envisioned that Corporate Average Fuel Economy (CAFE) credits would launch a market for flexible fuel vehicles that had little to do with alternative fuel use. Because EPACT specifies only the acquisition of AFVs—not the use of alternative fuel—we have EPACT-covered fleets that purchase flex-fuel vehicles, but never purchase alternative fuel.

EPACT has had a noticeable effect on the number of AFVs being acquired. Since 1992, when EPACT was enacted, the number of AFVs in the federal fleet alone has risen from approximately 3,000 vehicles to its current level of approximately 33,000 vehicles. In total, the number of AFVs in use has increased from approximately 251,000 (in 1992) to its current level of approximately 456,000. Alternative fuel use during that period has increased from 229 million gasoline-gallon equivalents to 366 million gasoline-gallon equivalents, and replacement fuel usage [methyl tertiary-butyl ether (MTBE) and ethanol in gasohol] has risen from 1.9 billion gallons to 4 billion gallons.

Department of Energy (DOE) modeling has indicated that alternative fuel refueling stations would have to achieve penetration on the order of 10% or more before consumers would consider purchasing AFVs, a penetration significantly higher than likely to occur due to the EPACT fleet programs. DOE analysis also indicated that the fleet programs were unlikely to provide a sufficient catalyst to cause AFVs to "spill-over" into the consumer market. Congress became less enamored of sending millions to DOE to cover incremental costs for other federal agency AFVs; therefore, DOE's $20 million request for this purpose in fiscal year 1996 was not funded and deployment programs returned to approximately $7 million annually.

Wrestling with these issues, stakeholder groups began developing focused marketing strategies for each type of AFV. Natural gas proponents identified high fuel use medium- and heavy-duty vehicles, such as transit, delivery, and freight vehicles, as better candidates for use of alternative fuels. Heavy fuel users could benefit from the cost savings due to lower natural gas prices; heavy-duty natural gas engines were also significantly less polluting than their diesel counterparts. Electric vehicle proponents began to focus on selected vehicle applications, such as delivery vehicles in dense urban environments where the zero emissions of an electric vehicle could compensate for its lower range. Because propane has higher energy content than other alternative fuels, propane vehicle advocates began to focus on light-duty trucks that required longer range in areas of the country where propane was already successful. In short, alternative fuel proponents were beginning to recognize the benefits of pursing success in specialized markets rather than the competitive light-duty fleet market. State and local efforts encouraged these budding efforts by providing incentives and implementing regulatory programs for heavy-duty vehicles. The DOE Clean Cities program supported these efforts through its growing grant program.

This specialized market approach allowed for more focused programmatic efforts. Congress established an AFV program for airports, providing $20 million in fiscal year 1999 to the Federal Aviation Administration to implement a targeted development program for infrastructure and vehicle use at 10 major airports. Congressional support for DOE grant programs has increased over the last 3 years. Automaker and engine manufacturer focus in specialized markets has also led to breakthroughs. For instance, 20% of all new transit orders in the United States are for natural gas-powered vehicles. In addition, alternative fuel shuttles are commonplace at major airports, and the U.S. Postal Service has ordered 500 electric vehicles with the potential for thousands more. AFV development has also expanded off-road and onto two-wheels, where significant energy and air quality gains are possible and creating potential new sales to help reduce costs.

**Dual-Fuel AFVs**

To date, the only dual-fuel vehicles produced have been light-duty vehicles capable of operating on natural gas and gasoline or propane and gasoline. (Dual-fuel vehicles are distinguished from flexible-fuel vehicles in that they have two separate fuel systems and they can only use one fuel at any one time.) At first blush, it would seem that dual-fuel vehicles would be the answer to developing an alternative fuel infrastructure. Unfortunately, it has not worked out that way. Most dual-fuel vehicles appear to have been acquired to meet EPACT requirements, but then only use gasoline as fuel. The fuel cost savings of using alternative fuels is not sufficiently large to encourage dual-fuel vehicle owners to try to maximize their use of alternative fuel, if they use it at all. Even when using alternative fuel, the emissions benefits of dual-fuel vehicles are compromised by evaporative emissions from the gasoline fuel system.

**Priority Strategies for the Future**

For the next 5 years, additional strategic development will be needed. A fresh approach will be required to continue encouragement of AFVs. More effort should be invested in the new strategies that address the rapid introduction of advanced technology vehicles, such as hybrid and fuel cell vehicles. Together, these fuel and vehicle strategies must create complementary programs that accelerate the adoption of transportation technologies that will reduce oil consumption and improve the environment. Elements of these new strategies may include:

- Emphasis on development of refueling, service, and training infrastructure;
- Focus on local market development that meets community needs, such as transit or airport applications;
- Promote the use of some alternative fuels as blends to help improve the quality of conventional fuels and extend fuel supply;
- Evaluate and promote energy saving applications that don't require wholesale vehicle or fuel changes, such as auxiliary power units for trucks that reduce idling and pollution; and
- Develop industry partnerships to expand market research and information dissemination for all types of energy and environmentally preferable vehicles

**Marketing Strategies**

Manufacturers are pursuing a variety of strategies to market AFVs to fleet buyers. These include the production of flyers and brochures targeted at specific areas of the fleet market, the production of Internet websites designed to highlight each manufacturer's alternative fuel offerings, and participation in various programs such as the DOE Clean Cities Program. Manufacturers are also participating in the DOE Clean Cities Program's "Advancing the AFV Choice" marketing seminars being held in Clean Cities across the nation. Manufacturers are also placing advertisements for their AFV offerings in fleet publications. To heighten awareness of AFVs among the general public, manufacturers are also cooperating in the production of educational materials for use in schools. They are also sponsoring activities such as FutureTruck and the Tour de Sol.

**Incentives**

A number of incentives are available to reduce incremental costs of AFVs for U.S. purchasers, from both the federal and state governments. The federal government offers a tax deduction of $2,000 to $50,000 (depending on vehicle size) for the purchase or conversion of qualified AFVs, and a credit is available for 10% of the purchase price of an electric vehicle, up to $4,000. Thirty-five states offer some sort of AFV incentive, including Arizona, which offers incentives that include a 95% reduction of license taxes, a $7,500 state income tax credit for light-duty vehicles, and no state taxes on alternative fuels. Legislation under consideration in Congress would significantly expand incentives for alternative fuels, AFVs, fuel cell vehicles, and hybrid vehicles, without negatively affecting the highway trust fund.

**Market Locations and Regional Sales Specifics**
Infrastructure considerations are a major influence on AFV sales. Availability of infrastructure in a given area for a given fuel will dictate whether or not vehicles using that fuel will be popular (or even available) in that area. Also, the availability of infrastructure itself can vary from region to region depending on the availability of the alternative fuel. For example, propane vehicles are popular in rural areas, because of propane's availability in rural areas as a home heating fuel. Propane is especially popular as a motor fuel in Texas, because of that state's abundant natural supply of the fuel. Natural gas vehicles can be found throughout the United States, because the country has an extensive natural gas pipeline system providing the fuel to most areas. Although ethanol vehicles are sold throughout the country, the ethanol vehicle infrastructure is centered in the corn-producing states in the Midwest.

In some cases, AFV sales can dictate the construction of infrastructure. Electric vehicles are offered predominantly in California and Arizona because of the favorable climate in those states. Auto manufacturers felt that the warm southwestern climate offered the most favorable environment for these vehicles, and thus vehicles such as the General Motors EV1 were offered only in those two states. In this case, the electric vehicle infrastructure was constructed as a result of the increasing numbers of electric vehicles being introduced.

## RESEARCH NEEDS
Alternative transportation fuels continue to meet substantial challenges to their implementation and use, despite many years of progress. Except for fuel cell vehicles, most of the vehicular technical problems have been solved and the deployment emphasis has been directed to infrastructure and implementation challenges. All of the alternative fuels would benefit from increased public awareness and development of a consensus as to what role they should play in our transportation energy market. The following cites some of the most basic challenges facing each alternative fuel.

**Natural Gas**
The primary challenge facing natural gas vehicles is infrastructure development. Refueling infrastructure for natural gas vehicles is considerably more expensive than for conventional fuels. However, if high utilization can be achieved, life-cycle costs of natural gas vehicles can be lower than conventional vehicles, even before accounting for price spikes due to shortages. An underappreciated advantage of natural gas is that it is domestic, unaffected by petroleum fuel shortages, and less vulnerable to acts of terrorism than petroleum fuels. More consideration should be given for its energy security value for use in critical missions such as mail delivery, bus service, transportation of critical goods, and other government services. The California power crisis has created the incorrect impression that natural gas is too expensive to compete in the transportation fuel market. Advanced natural gas engine and storage development could improve fuel efficiency and range.

**Propane**

A primary hurdle facing propane is a lack of vehicle models. In the past, most vehicles using propane relied on conversion systems. This is becoming increasingly more difficult, although some systems do exist. Although a national distribution system exists for propane, propane marketers are reluctant to sell it as vehicle fuel because the profit margins for other uses are better. In addition, propane vehicles are still restricted from using some bridges, tunnels, and parking garages.

**Methanol**
The future potential for methanol lies primarily with fuel cell vehicles. Methanol faces a substantial health and safety challenge in that it will be held to a very high standard for leakage into the groundwater based on the experience with MTBE. Methanol used in fuel cells will most likely be pure methanol in that it will not contain significant amounts of hydrocarbons (such as in M85) to make its flame luminous. It is unclear whether society will be able to deal with a fuel that burns without a luminous flame.

**Ethanol**
The use of ethanol as an alternative fuel has achieved considerable success and it appears posed for continued future success as a blending component of gasoline. The economics of blending ethanol in gasoline and the oxygenate mandate of reformulated gasoline hinder the use of ethanol directly as a fuel (i.e., as E85), despite there being more than one million ethanol flexible fuel vehicles on the road today with the prospect for almost one million such vehicles being added each year. To expand beyond the blend market may well require adding cellulosic feedstocks to existing corn and starch feedstocks. So far, production of ethanol from cellulose has not reached the commercial phase. Even where E85 is available, the highly competitive gasoline marketing systems make it very difficult for marketers to implement, because of underutilization of their equipment until a critical mass of ethanol flexible fuel vehicles begin to use E85.

**Electricity**
The most important problem facing electric vehicles is the cost and performance of batteries. Another challenge facing electric vehicles is the impression that there is insufficient electricity for them in addition to the traditional uses of electricity. The public is unaware that if electric vehicles are recharged overnight, sufficient power capacity exists for them and more efficient utilization of our electric generating infrastructure would result.

**Biodiesel**
Other than cost, there are relatively few issues confronting biodiesel. Used typically in a 20% blend with conventional diesel fuel, relatively little new infrastructure is needed to keep it segregated. But emissions benefits are small and ultimate production capacity is a question. Does reliance on biodiesel defer investments in other AFVs and infrastructure with better payoffs? Another issue for biodiesel is the yield per acre, which is quite low relative to ethanol, for example.

**Hydrogen**
Hydrogen faces a very significant public relations problem—its association with the Hindenburg disaster. Despite the fact that many people survived the Hindenburg disaster and that the lower flame temperature of hydrogen may be partly responsible, in the public's mind hydrogen remains

a very dangerous fuel. Some research has been done suggesting that hydrogen poses no greater a fire safety risk than natural gas. Beyond public acceptance, building codes would need to be updated to include hydrogen for refueling facilities, parking garages, and home garages. Hydrogen storage pressures of 5,000 to 10,000 psi are being proposed to give hydrogen fuel cell vehicles sufficient operating range. These pressures are well beyond those used for natural gas (i.e., 3,600 psi) and operating experience is needed to determine the risks such pressures might pose. There is also the question of where the hydrogen should be made—at large centralized plants or at every refueling station? Infrastructure development for hydrogen-fueled vehicles will be a significant barrier and strategies that use natural gas refueling as a stepping stone to gaseous hydrogen infrastructure should be evaluated.

**Gas-to-Liquid Fuels**

It is as yet unclear whether these fuels will be used in blends with conventional diesel fuel or separately as a premium diesel fuel. Either way, no new infrastructure is required except to keep them segregated when necessary. Like biodiesel, emissions benefits are small in existing engines, although GTL fuels will enable advanced emission control devices for diesel engines and should result in lower emissions of toxics compared with conventional diesel fuels. After 2007, the only emissions benefit may be lower toxics.

**FIGURE 1 U.S. transportation petroleum gap: Transportation in the United States is projected to be increasingly dependent on imported petroleum (SOURCE: Energy Information Administration).**

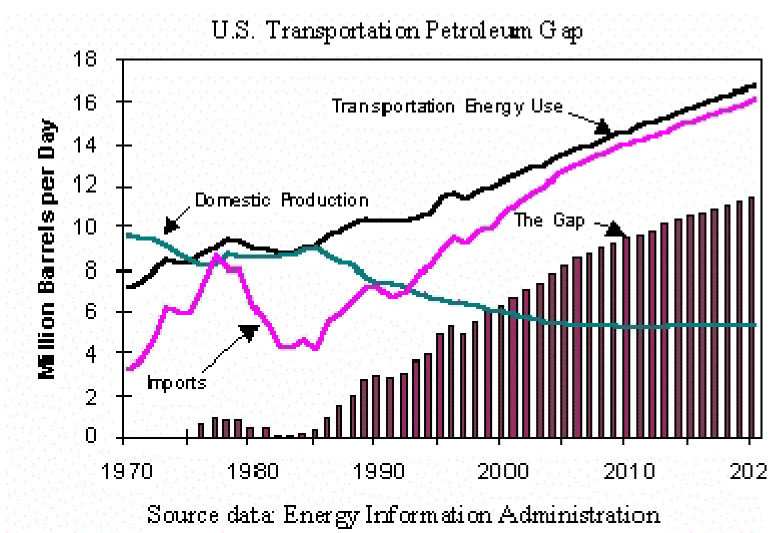

FIGURE 2 Projection of transportation fuel demand.
Source: EIA Annual Energy Outlook, 2002.

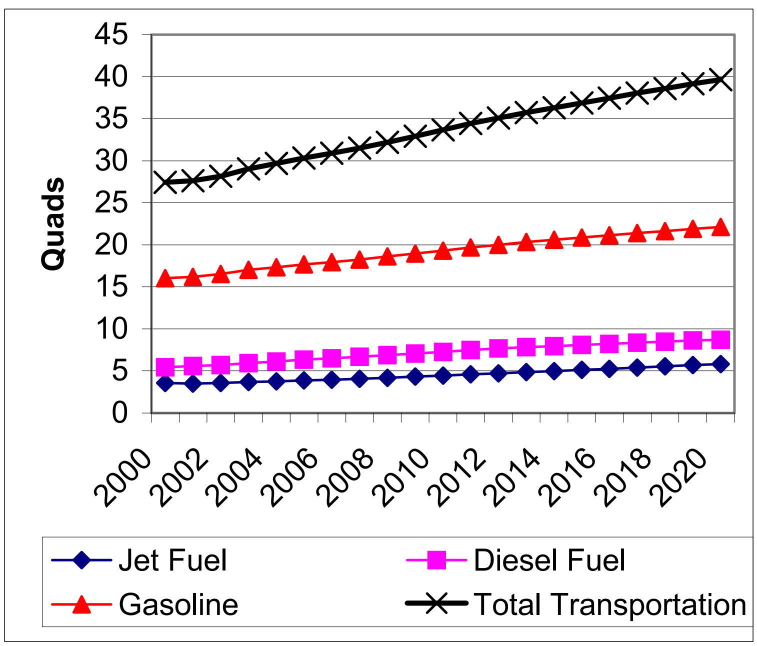

**TABLE 1 Alternative Fuel Use 1992 and 2001, Million-Gasoline Gallon Equivalent**

| Alternative Fuel | 1992 | 2001 | % Change |
|---|---|---|---|
| LPG | 208.1 | 243.2 | 17 |
| CNG | 16.8 | 107.5 | 640 |
| LNG | 0.6 | 7.5 | 1,200 |
| Methanol (M85) | 1.1 | 0.9 | –18 |
| Methanol, Neat | 2.5 | 0.4 | –80 |
| Ethanol (E85) | 0.02 | 4.6 | 21,900 |
| Ethanol (E95) | 0.09 | 0.05 | –45 |
| Electricity | 0.4 | 2.1 | 580 |
| Total | 229.6 | 366.3 | 60 |

LPG = liquefied petroleum gas; CNG = compressed natural gas; LNG = liquefied natural gas.

RESEARCH NEEDS STATEMENTS

# Energy and Alternative Fuels

### 1. Analysis of Alternatives to CAFE for Increasing Fleet Fuel Economy

**Problem Statement**
There are several reasons for the government to intervene in the new vehicle market to improve fuel efficiency. For example, the economic impacts of carbon dioxide accumulation in the atmosphere and increasing reliance on imported oil are not normally reflected in the market for new vehicles. The CAFE standards passed by Congress in 1975 attempted to address societal concerns about fuel availability and price. Although the CAFE standards have been successful in improving vehicle fuel efficiency, there have also been some unintended consequences, such as possible impacts on safety, unequal impacts on different manufacturers, and possible diversion from amenities valued by consumers (performance, utility, luxury). The recent National Research Council (NRC) report, "Effectiveness and Impact of CAFE Standards," evaluated the impact of the CAFE structure and found that

> Raising CAFE standards would reduce fuel consumption below what it would otherwise be; however, other policies could provide the same end at lower cost, provide more flexibility to manufacturers, or address inequities arising from the present system. Possible alternatives that appear to the committee to be superior to the current CAFE structure include tradable credits for fuel economy improvements, feebates, higher fuel taxes, standards based on vehicle attributes (for example, vehicle weight, size, or payload), or some combination of these [Finding 10].

**Proposed Research**
The purpose of this research is to follow up on the NRC committee work on CAFE and provide analyses of different alternatives to CAFE. An evaluation of different alternative CAFE structures would be performed including, but not limited to

- Fuel economy-based systems, where each manufacturer gets a fleet-average miles per gallon target. An example is modification to the existing CAFE structure.
- Attribute-based standards, such as weight, size, and class.
- A market-based system, such as continuously variable manufacturer incentives (feebates).
- Tradable credits to determine their impact with fuel economy-based systems and attribute-based standards.

The analyses should *not* consider taxes or other mechanisms directed primarily at consumers instead of manufacturers.

The goal is to provide comprehensive analyses that could be used to explain each alternative; that is, how the concept works and the impact on cost, manufacturer flexibility, fuel consumption reduction, safety, and inequities between manufacturers. To help illustrate the various impacts, the analyses should include likely manufacturer response. The analysis of each option should include the economic efficiency of the system, equity (or fairness), and potential for gaming (loopholes).

**Cost:** $400,000–$500,000
**Duration:** 24 months

### 2. Analyzing the Sustainability of Various Alternative Fuels and Advanced Technology Vehicles in Selected Niche Vehicle Markets

**Problem Statement**
Early introduction of alternative fuel and advanced technology vehicles is often focused on specialized vehicle markets, rather than the mass market. These markets, such as airport shuttles, transit buses, and taxis, share common characteristics that may be more amenable to new fuel infrastructure or adoption of new technology. However, little analysis has been done to determine if they are large enough, individually or collectively, to create sustainable supply and demand of specific alternative fuels and vehicles. For example, if 20% of all transit buses in the United States are natural gas, will engine and chassis manufacturers be able to profitably manufacture and sell natural gas engines and buses? Little is also understood about the energy benefits of successful market applications taken alone or whether such applications will lead to expanded use of alternative fuels and vehicles in the mass market. Furthermore, the attributes of such markets attract more than one new fuel and vehicle technology, making it even more difficult to estimate the sustainability of each.

**Proposed Research**
This research should address the numerous technology and market opportunities and barriers for the use of specialized vehicle markets as introductory markets and "launching pads" for alternative fuel and advanced technology vehicles including

1. A comprehensive identification and characterization of vehicle market segments that are being considered as first applications for alternative fuels, advanced conventional fuels, and advanced vehicle technologies. This should include the number and type of vehicle sales; quantity of fuel consumed; costs; the type and level of subsidy; suitability of vehicle and fuel characteristics to specialized market; and distinction between light-, medium-, and heavy-duty applications.
2. An assessment of manufacturer willingness to develop, manufacture, sell, and service various alternative fuels and advanced vehicle technologies to a niche market over an extended period of time. What factors change the willingness to sustain presence in the niche market?
3. As assessment of fuel provider willingness to establish and maintain a fuel infrastructure and produce, distribute, and sell various fuels to these markets. What factors change the willingness to sustain presence in their market?
4. The capacity of specialized markets to absorb one or more new fuels and vehicle technologies simultaneously on a sustainable basis. What factors change the capacity of fleets or consumers in these markets to create sustainable demand? How does competition within these markets affect this capacity?

5. How to distinguish between self-sustaining supply and demand, and various and presumably higher levels of supply and demand that could be sustainable because of government policy, correction of market failures, or consumer attitudes.

6. An assessment of the potential for various specialized markets to serve as launching pads for the broader use of alternative fuels and vehicle technologies. What are the factors that increase this potential? Are some fuels and technologies suitable only for these markets?

7. The energy and environmental impacts of sustainable specialty markets taken alone or collectively, and under various scenarios where niche markets serve as a critical launching pad for fuels and vehicles to enter the mass market.

8. A summary of the conclusions about the characteristics of these successful markets should be prepared.

**Cost:** $500,000
**Duration:** 18 months

## 3. Potential Travel Responses to Alternative Highway Pricing and Financing Systems and the Impact on Fuel Consumption and Greenhouse Gas Emissions

### Problem Statement

An extensive body of recent research shows that the current pattern of highway travel imposes large costs such as congestion and vehicle emissions that are not borne by the motorists who impose them. It also demonstrates that many of the costs of highway travel that are borne by individual users, such as those for vehicle ownership, parking, and insurance, are paid in fixed increments, even though they may arise as a function of individual trips or vehicle mileage. There remains some need to examine which specific categories of "external" and fixed costs associated with motor vehicle usage actually vary incrementally with the number of trips taken or miles traveled. These costs could thus logically be imposed on a per-trip or per-mile basis. Such charges for highway travel could significantly revise travel decisions by highway users to select other modes, times, and frequencies.

Advances in microelectronic technology currently permit the deployment of nonintrusive, low administrative cost mechanisms for assessing these costs to the specific vehicles and travelers who impose them. This situation affords the opportunity for a comprehensive overhaul of the current structure of highway transportation pricing and financing, including a move away from the current reliance on mechanisms such as motor fuel taxes, vehicle registration fees, and property taxation to finance road system construction, maintenance, and administration. This project would evaluate the potential magnitude of behavioral responses to new forms of pricing and the likely levels of such changes, including changes in the volume and patterns of trip-making and the energy efficiency of motor vehicles, and assess the implications of these changes for energy consumption and greenhouse gas emissions in urban transportation.

### Proposed Research

The proposed research would be conducted in several steps:

1. Identify external costs of highway transportation that are sensitive to changes in the level of vehicle-miles traveled and select the best available estimates of their magnitude and reasonable range from the available literature.

2. Identify traveler-paid costs that vary with mileage traveled but are commonly paid in fixed increments because of institutional arrangements, custom, or other reasons, and estimate their per-mile values.
3. Identify the structure and level of taxes currently used to finance transportation infrastructure investments, highway maintenance, and road system administration, including motor fuel, taxes, vehicle registration fees, local property taxes, etc.
4. Identify alternative pricing structures for (1) each component of costs now covered by motor fuel or other transportation-related taxes, (2) each motorist-borne cost component now paid in fixed increments, and (3) each empirically significant external cost element associated with highway travel. One of the alternatives should represent an attempt to maximize the social welfare of the highway transport system by economically efficient pricing.
5. Use available behavioral theories and empirical evidence (e.g., price elasticities) to develop a consistent analytic framework for predicting potential behavioral changes in response to the replacement of existing fuel and other transportation taxes and fees with alternative charge structures based on "internalizing" external costs of highway travel and converting fixed vehicle and driving-related expenses to a per-mile or other variable basis. Behavioral changes of interest should include household vehicle ownership levels and vehicle type choices, household-level or fleet-wide average vehicle utilization and total vehicle-miles traveled, vehicle and fleet fuel economy, trip characteristics (frequency, timing, length, etc.), density of development, motor fuel consumption, and emissions of National Ambient Air Quality Standards criteria pollutants, and greenhouse gases.
6. Assess the willingness of the public to accept new pricing systems and technologies (vehicle based and nonvehicle based) and the perceived privacy issues.

**Cost:** $300,000
**Duration:** 18–24 months

### 4. Reassessing Modal Energy Intensities

**Problem Statement**

Energy intensities (energy use per unit of activity) are basic information for forecasting, policy analysis, planning, and monitoring progress toward national energy and environmental goals. The most recent comprehensive study of passenger and freight energy intensities is now more than 20 years old. Energy intensity values are essential for predicting the impacts of changes in the structure of passenger and freight transportation. Because greenhouse gas emissions are closely linked to energy consumption, intensity numbers are a key factor in modeling the global warming impacts of different transportation activities. In general, only the most aggregate energy intensity values are readily available (e.g., energy use per total revenue passenger-mile for air travel, energy use per vehicle-mile for automobile travel, etc.). In addition, for some modes (e.g., truck freight), even the most basic estimates of energy use per ton-mile are not available. There is considerable value to having comprehensive, consistent, and objective measures of modal energy intensities with sufficient detail to be widely useful for the kinds of analyses mentioned above. Developing such estimates requires a substantial research effort.

**Proposed Research**

Comprehensive, consistent, and objective measures of transportation energy intensity will be developed for all transportation modes, both passenger and freight, by mode and function, and at different spatial scales (e.g., national, regional, metropolitan). The level of detail should reflect analytical needs as well as the availability of reliable and accurate data. Detail is important to ensure valid comparisons across modes and functions and to improve the accuracy of derived estimates, such as greenhouse gas emissions.

1. A review of United States and international literature will be conducted both to obtain modal energy intensity estimates for comparative purposes and to identify data sources and methods.
2. Both the literature and relevant agencies will be surveyed to identify and evaluate the most important uses of energy intensity numbers.
3. Based on the availability of data and the needs for energy intensity estimates, the modal, functional, and spatial structure of the intensity estimates to be derived will be specified. Methods and data sources for developing the estimates will be specified.
4. The methods will be implemented as a computer model (e.g., a spreadsheet) so that estimates can be made for both the past and future, according to the availability of data.
5. The best available data, together with engineering and transportation modeling methods will be used to develop consistent, comprehensive estimates of energy intensities.

The products of this research will be a final report covering items 1–3 and 5, and a computer model of item 4, together with instructions for its operation.

**Cost:** $250,000
**Duration:** 18–24 months

### 5. Assessing the Limits of Biofuel Supply for Transportation

**Problem Statement**
Biofuels are becoming more popular for reasons that include mandates for oxygen content in gasoline, domestic energy security, compatibility with existing vehicles and fuels, favorable emission characteristics, and low net greenhouse gas production. However, there may be practical limits to the contribution that biofuels can make to fuel supplies. These limits include the number of biomass resources available, competition with other uses of biomass, competition for arable land to produce biomass resources, production costs, limitations on blend percentage (e.g., vapor pressure limitations for ethanol in gasoline, cold-flow performance for some types of biodiesel), limitations on production incentives, and availability of vehicles that can use the fuel (e.g., flexible fuel vehicles that can use E85). Options for increasing biofuel quantities include expanding the resource base that can be used, developing advanced production technologies (i.e., cellulosic ethanol production), and imports from foreign countries. Global climate change may affect future biofuels production because of shifts in arable land. In addition, little is known about the stability of biomass feedstock production.

**Proposed Research**
The contribution that biofuels can make to the U.S. transportation fuel market shall be estimated. The maximum practical production potential for ethanol and biodiesel and other potential

biofuels shall be estimated taking into account the existing resource bases for each, the economics of competing uses, and a range of incentives. Long-term potential (20 years or more from now) for biofuels production and use shall be estimated including consideration of additional resources, advanced technology production processes, the impact global climate change will have on the resource base, and the potential for imports from foreign countries. A sensitivity analysis shall be conducted of the factors affecting biofuels production. Technical limitations on the use of biofuels in vehicles shall be taken into account when estimating the total amount that could be used as fuel. This shall include an assessment of whether production incentives can lead to future production that is self-sufficient.

**Cost:** $400,000–$500,000
**Duration:** 15–18 months

### 6. Assessment of Pathways to Fuel Cell Vehicles

**Problem Statement**
An ever-growing interest in the promise of fuel cell vehicles has led to a variety of efforts to accelerate its commercial introduction. From the private sector, eight major auto manufacturers, DaimlerChrysler, Ford, General Motors, Toyota, Honda, Nissan, Volkswagen, and Hyundai, are collaborating with federal, state, regional, and local government agencies under the auspices of the California Fuel Cell Partnership (CAFCP). Honda has announced the limited introduction in 2003 of a fuel cell car for the U.S. market designed for fleet use and Toyota reports that in 2003 it will market a Highlander (sport utility vehicle platform) fuel cell vehicle in Japan. Efforts at the government level include the DOE's long-standing effort on fuel cell development for light-duty vehicles, the January 2002 announcement of DOE's Freedom CAR program (with General Motors, Ford, and DaimlerChrysler), and numerous fuel cell programs proposed by energy legislation in the 107th Congress. The sum of the current and planned investments from both the private sector and government in this technology is significant. To maximize the return on investment from these efforts a comprehensive assessment of pathways to fuel cell vehicles is essential.

**Proposed Research**
This project effort will conduct a comprehensive assessment of pathways to the successful mass-market commercialization of fuel cell vehicles in North America by

- Reviewing previously related efforts from the CAFCP, the Argonne National Laboratory, etc.;
- Examining the impact of the application of fuel cells for other markets including stationary, residential, portable, and mobile power;
- Evaluating options for the early introduction of fuel cells into transportation applications–transit buses (Federal Transit Administration, CAFCP, European demo program), and niche markets;
- Evaluating transition options–natural gas for gaseous fuel, hybrid electric for electric drive;
- Evaluating the narrowing advantages of fuel cell vehicles against competing technologies–conventional gasoline and diesel, hybrid electric, and alternative fuels;

- Evaluating infrastructure requirements for on-board and off-board reformation;
- Assessing benefits in terms of air quality/greenhouse gas emissions, energy security, and global competitiveness; and
- Describing prospective pathways with associated costs, benefits, and potential barriers.

**Cost:** $450,000
**Duration:** 24 months

### 7. ANALYZING PATHWAYS FOR THE TRANSITION TO A HYDROGEN INFRASTRUCTURE

**Problem Statement**
The Bush administration has announced a major initiative to develop and deploy hydrogen utilization technologies, and to produce and deliver hydrogen energy in an affordable, safe, and convenient manner ("A National Vision of America's Transition to a Hydrogen Economy—To 2030 and Beyond," February 2002). Clearly, hydrogen has the potential to lessen dependence on foreign petroleum and reduce pollution and greenhouse gas emissions. However, achieving this potential is no small task. Developing and deploying hydrogen vehicles is a formidable undertaking. Coordinating infrastructure development with deployment is likely to be even more of a challenge.

Conventional highway fuels are distributed by means of what may be termed a petroleum model. Product terminals receive various grades of petroleum either directly from refineries or from a tanker, pipeline or truck and distribute it to local refueling facilities. Depending on the feedstock and conversion process, the hydrogen supply infrastructure could follow this model or one based on the natural gas delivery system (relying primarily on gaseous pipelines). Alternatively, hydrogen could be centrally converted to electricity. In addition to uncertainties regarding the infrastructure model itself, additional uncertainties revolve around the individual components of the supply infrastructure (e.g., production by means of steam methane reforming vs. coal gasification with carbon sequestration vs. thermochemical water splitting from high-temperature nuclear reactors), and the evolution of that infrastructure over time. Presumably, initial components of the infrastructure would include portions of the current hydrogen supply infrastructure (primarily captive production by petroleum refiners and ammonia, methanol, and merchant gas producers with distribution by pipeline, rail, and truck) and the existing petroleum, natural gas, and/or electricity supply systems. As volumes increase, the pathway could increasingly diverge from these components, eventually evolving into a dedicated hydrogen infrastructure.

**Proposed Research**
The work will be divided into two distinct phases, the first identifying components of one or more end-state hydrogen supply/distribution infrastructures, and the second detailing potential transitions to those end-states.

*Phase 1*
Define potential end-state infrastructures incorporating portions of petroleum, natural gas, and/or electricity supply models and estimate cost of components. Options should include alternative hydrogen supply sources and production processes, technologies for sequestering or otherwise

capturing carbon, distribution and offboard storage, and refueling facilities. Identify potential barriers (e.g., perceived risk, codes, and standards).

*Phase 2*
For the most promising alternatives identified in Phase 1, characterize 1 to 3 potential pathways for infrastructure development or evolution over time. Develop rough cost estimates associated with infrastructure components and compare pathway costs with initial estimates of end-state costs.

**Cost:** $1,000,000–1,500,000
**Duration:** 30–36 months

## 8. Fuel Economy and Global Warming: Understanding Consumer Behavior and the Increasing Awareness of the Link Between Fuel Consumption and Global Warming

### Problem Statement
Surveys in the United States indicate that at least 75% of the general public believe that global warming is a concern that needs to be addressed. However, there has been little action in the United States in support of this expressed concern. This is partly because most people do not understand that there is a link between vehicle fuel efficiency and global warming gases. Unlike criteria air pollutants, which can cause health problems and damage the environment and property, where public outcry and support has led to tough emission standards, there has been little public demand to do anything about global warming gases. As a consequence, Congress has done very little to improve vehicle efficiency since passing the CAFE standards in 1975.

Vehicle purchasers generally rate fuel economy very low on their priority list for selecting a vehicle. It is also very difficult to market improved fuel efficiency to consumers, in part, because vehicle purchasers usually severely discount the value of the fuel savings. Although public research on the value consumers place on fuel savings does not exist, sources with proprietary data (manufacturers, J.D. Powers, etc.) indicate that the average consumer only values about the first 3 years, or 50,000 miles, of fuel savings.

### Proposed Research
The first goal of this project is to study and understand all aspects of consumer behavior—how they get information on fuel consumption, what they do with it, how it influences their purchase decisions, how much they value the fuel savings, and why they do not value fuel savings for the full useful life of a vehicle. The project should provide information that would help researchers assess the consumer's value of fuel savings. It should also include an assessment of how much energy security concerns might affect consumer decisions.

The second goal is to assess ways to increase public awareness of the link between fuel consumption and global warming. Different strategies should be assessed, including, but not limited to, consumer education campaigns, advertising, social marketing, and outreach to schoolteachers and administrators. Similar cases, such as the increasing public concern with criteria air pollutants, should be evaluated and assessed for relevant lessons.

A variety of research tools should be considered for each goal, including focus groups, surveys, and experimental economics.

**Cost:** $500,000–$600,000
**Duration:** 30 months

### 9. Develop and Analyze the Costs and Benefits of Transportation Strategies to Improve Energy Security

**Problem Statement**
Recent events associated with terrorism in the United States and turmoil in the Middle East has renewed attention to energy security issues, as a component of national security. Energy security objectives have been offered as one motivation for a variety of initiatives that pursue new transportation technologies, systems, or fuels. Energy security concerns are derived partly from the exercise of market power, concentrated in the hands of a few major oil-exporting countries. Another aspect of the problem is that many major oil suppliers are in politically unstable parts of the world, and there is a risk of oil market shocks from revolutions, wars, embargoes, and accidents. Transportation fuel supply, largely based on oil, is unstable. There have been 18 significant oil supply disruptions in last 50 years. Not all of these supply shocks led to major price spikes, but some led to large and sustained price increases. In the face of this unstable supply, demand for fuel is inflexible, especially in the short run, and particularly in the transportation sector. Therefore, supply disruptions can be and have been costly to the economy. There is a need to assess the merits of transportation strategies that promote greater energy security by reducing oil use or by increasing the flexibility of the transportation sector to respond to short run shocks in supply or price.

**Proposed Research**
This research will focus on the prospects for enhancing energy security with a variety of transportation initiatives. It will include the expected costs and benefits of measures that reduce oil demand over the longer term and measures that increase the flexibility of fuel demand or transportation services demand to adjust to sudden energy emergencies in the short run. Issues to be addressed include the benefits and costs of reducing long-run petroleum use through conservation (greater fuel efficiency) or substitution (of alternative fuels for petroleum fuels). In considering the displacement of oil use with alternative fuels, the study will compare strategies based on the use of alternative fuel vehicles with strategies that blend alternative fuels with conventional fuels. Attention will be paid to the effect of fuel diversification on supply risk, which depends in part on the extent to which the supply and price of alternative fuels is linked to that of petroleum fuels.

Examples of measures to promote greater short-run flexibility to be analyzed include establishing a vehicle fleet that relies on a greater diversity of transportation fuels, expanding the use or deployment of dual-fueled and flexibly fueled vehicles, or creating the capacity for modal shifts or shifts in trip-patterns during energy emergencies. A better understanding is needed of the relative cost-effectiveness of these measures in reducing the risks and costs of fuel supply shocks. An important contribution of this research will be a consistent analytical framework for comparing the relative energy-security merits of this diverse set of strategies. These strategies are both short run and long run, and create options and capabilities to quickly shift transportation energy patterns. Some consideration will be paid to possible local energy security benefits in specific transportation regions as well as national energy security benefits.

**Cost:** $400,000
**Duration:** 24 months

## 10. Information Required for Increasing the Energy Efficiency of Goods Movement

### Problem Statement

A lack of reliable data concerning the movement of goods throughout the economy severely hinders innovative planning for an efficient and competitive freight infrastructure for the 21st century. Information is required for aggregate and disaggregate activities involved in intercity and urban goods movement, which includes the types of operations and their ownership.

There is a need to develop a national, state and local information system for state and metropolitan planning organization planners to facilitate the introduction and evaluation of innovative major infrastructure improvements and investments that promote multimodal coordination to enhance the overall efficiency of goods movement

Heavy-duty trucks are a very visible source of urban congestion as a result of their imposing size, inadequate off-road loading facilities in older urban areas, the spectacular congestion events caused by truck accidents, and the visible pollution from their large diesel engines. Yet, planners know little about their movements, specific use patterns, loads, etc. National data collection efforts such as the periodic Vehicle Inventory and Use Survey and the Commodity Flow Survey provide useful data on national trends in goods movement and vehicle characteristics, but little is known about specific truck operations behavior and the opportunities for congestion relief, increased fuel efficiency in goods movement, and the reduction in damaging air emissions from heavy-duty vehicles (HDVs). The general growth in truck traffic together with the advent of e-commerce could exacerbate the problem, where it is expected that there will be more frequent services in urban areas with the increased use of vans and smaller trucks, by increasing energy consumption, emissions, and road damage. The availability of real-time traffic information from intelligent transportation system technologies offers planners, shippers, and truck operators the opportunity to improve energy and operational efficiency. The growth in rail and multimodal operations may increase economic efficiency and performance while reducing energy use as well as green house gases and conventional emissions.

### Proposed Research

*Phase I: Information Collection and Needs Analysis*

Based on the literature review and assessment of other information collection activities, the Phase I report will summarize what is known about HDV and other goods movement operations and how additional information could assist planners in developing improved plans. From this a work plan will be developed for the conduct of the Phase II data collection efforts. The work plan will specify the objectives of the data collection activities and provide a plan for the use of the information in improving goods movement fuel efficiency.

*Phase II: Information System Design and Development of a Web-Based Interactive Tool*

- Task 1—Design a freight activity database that will provide the framework for describing the activities of heavy-duty trucks and other modes. Data should be included on fleet characteristics such as number of vehicles, body types, goods carried, weights, areas of operation, engine types, energy efficiency technologies, operating behavior (starts, idle time, speed profile, fuel use, fuel efficiency, loads, trip length, etc.), and other data of interest for energy efficiency, air quality, and highway capacity planning.
- Task 2—Select two or three regions/states to develop a freight information database. The selection will be based on the availability of state and local freight information such as a multimodal management plan or an HDV emission information system. Selection will also consider the regional characteristics, types of goods moved, and other factors.
- Task 3—Develop the regional/state freight information system for selected regions. The information will be incorporated from secondary sources and from surveys and HDV monitoring activities conducted to fill data gaps.
- Task 4—Design surveys of truck, rail, water, and other goods movement operations in local areas to collect information needed to fill data gaps in the freight information system. Information collection activities may include surveys of shippers, shipping facilities, and carriers, as well as the instrumentation of vehicles to collect detailed operational data.
- Task 5—Conduct surveys and instrument vehicles as needed to complete the information system for each region and finalize the data set. Provide and demonstrate the information in each selected region.
- Task 6—Develop a web-based interactive tool comprising a freight information system for energy, environmental, and transportation planning. The tool will identify sources of data and methods for developing local information to supplement what is known from other studies, and will provide a model database, including default values for most cells. Instructions for the use of the information and the calculation of project benefits will also be developed.
- Task 7—Provide a detailed final report that will document all information, processes, procedures, and data that were reviewed, prepared, or developed in the course of this study.

**Cost:** $375,000
**Duration:** 24 months

## IMMEDIATE TRANSPORTATION AND ENERGY RESEARCH (SHORT TERM)

As a result of the research needs conference, the transportation and air quality research needs work group identified 10 research projects that must be accomplished over the next 5 years. However, the work group also identified three critically important and relatively inexpensive projects with immediate pressing needs. These projects must be accomplished in the near term and cannot wait for the standard 1- to 3-year research approval and implementation process. The work group believes that consulting firms could quickly accomplish these six projects for less than $100,000 per project. The three projects are as follows:

### 11. Emissions and Fuel Economy Testing of Hybrid Electric Vehicles (HEVs) to Specify a New MOBILE Class

**Problem Statement**

HEVs have been certified at California Ultra-Low Emission Vehicle and Super low Emission Vehicle levels to be far cleaner as a class than conventional gasoline vehicles. MOBILE6, however, adds only one class-compressed natural gas vehicles, which are cleaner as a class than gasoline vehicles. HEVs also realize greater increases in fuel economy relative to conventional vehicles (CVs) in congested urban driving than in highway driving. Because HEVs trade increased vehicle cost for decreased fuel cost, it is logical to believe that consumers will selectively purchase and use HEVs where gasoline prices are high, that is, in congested urban driving.

**Proposed Research**

This research will measure the emissions and fuel economy of HEVs for a range of driving cycles, from very slow average speeds like the NYC cycle to high speeds (such as US06). Particular attention will be paid to including conditions prevalent during violations of ozone standards and to measuring the effects of HEV regenerative braking. Comparable CVs from the same manufacturer will be tested on the same dynamometer to benchmark emissions differences at all speeds. Results will be provided to the Environmental Protection Agency in a form suitable for use in the TRansportation ANalysis SIMulation System (TRANSIMS) and for possible use in a future version of the MOBILE model.

**12. Developing Better Ways to Measure the Number of Alternative Fuel and Advanced Technology Vehicles**

At present, there is no standard procedure for identifying alternative fuel and advanced technology vehicles in the on-road fleet. Although they could be identified by decoding vehicle identification numbers, this is a painstaking process requiring considerable knowledge of the engine families in which alternative fuel or advanced technology options are offered and other identifying characteristics that would differentiate these vehicles from otherwise comparable nameplates using conventional fuels and engines.

This study will investigate alternative classification methods in use in various states, overseas, and by different manufacturers. A list of potential options will be developed and compared on such criteria as accuracy (i.e., ability to correctly categorize vehicles), processing speed, ease of implementation, and cost to establish and maintain. The results of the comparison will be provided to appropriate local, state, and federal agencies to assist them in the selection and use of improved classification methods.

**13. Assessment of Fuel Cell Vehicle Societal Benefits**

The goal of this study is to make a solid case for public support for fuel cell vehicles and the needed fueling infrastructure. The objective is to develop a collective and unbiased understanding of the benefits associated with the successful commercialization of fuel cell vehicles in the mass market. The successful commercialization of fuel cell vehicles will most likely require significant public assistance. Public support will be critical in the near-term although near-term societal benefits are few. The case for fuel cell vehicles appears to indicate long-term societal benefits—decreased use of fossil fuels and nondomestic fuel sources, improvements in urban air quality, reduced sources of groundwater and open water contamination, a reduction in greenhouse gas emissions, and other societal benefits. Identifying and characterizing these benefits will enhance public support for the near-term public investment needed.

# Environmental Information Management

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RESOURCE PAPER

# Environmental Information Management

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Environmental analysis in regards to transportation actions requires an effective approach to data collection, storage, management, retrieval, and sharing. The basic requirements that must be fulfilled to effectively carry out these types of data management activities are well known. Even so, no single agency has developed a universal solution that other agencies might adapt. Furthermore, many details of different aspects of environmental information management have not been worked out and are worthwhile topics ripe for research.

This paper recommends research regarding environmental information management. The approach taken is (1) identify the key components of environmental management systems (EMS), (2) emphasize those elements that pertain to environmental data and information management, and (3) identify current and future research needs.

The following two approaches to EMS are identified and discussed:

- An EMS compliant with the International Standard Organization (ISO) standard 14001.
- The concept for an Environmental Information Management and Decision Support System (EIM&DSS) developed under National Cooperative Highway Research Program (NCHRP) Project 25-23.

## ISO 14001 Environmental Management System

A large number of private U.S. firms, many transportation agencies around the world, and a few state departments of transportation (DOTs) in the United States have developed or embarked on developing an Environmental Information Management System that is compliant with the ISO 14001 standard.

The ISO 14001 standard is consistent with the "Plan, Do, Check, Act" cycle of continuous quality improvement and consists of the elements shown in Figure 1.

The following is a brief description of the core elements of the ISO 14001 standard.

### Establish Environmental Policy

Top management defines an environmental policy that fits the nature, scale, and impacts of the organization's activities, products, and services; commits the organization to continual improvement and pollution prevention; complies with environmental laws and regulations; offers a framework for establishing and periodically reviewing environmental objectives and targets; provides for documentation, implementation, maintenance, and communication to all employees; and is accessible to the public.

### Plan to Improve Environmental Outcomes

The organization must plan the environmental aspects of its operations, activities, services, or products that affect the environment; address legal and other requirements pertinent to the environmental aspects; and establish objectives and targets regarding each pertinent function and level in the organization consistent with the organization's environmental policy and that contribute to pollution prevention.

**Implement and Operate to Achieve Objectives and Targets**
The organization must implement an environmental management program for achieving the organization's environmental objectives and targets. The management program must address responsibilities, resources (human resources, skills, technology, financial resources), and time frame or schedule. The implementation and operation approach must also address training, communications, system documentation, document control, operational control, and emergency preparedness and response.

**Checking and Corrective Action**
The organization must periodically monitor and measure environmental performance, track the effectiveness of its controls, and assess progress in attaining procedures for addressing nonconformance and taking corrective and preventive action. The organization must maintain records concerning environmental matters and periodically conduct an EMS audit.

**Management Review**
The EMS is required to have a management review process to assess its suitability, adequacy, and effectiveness over time, and to address needs for change to policy, objectives, and other elements of the system in light of the commitment to continuous improvement.

## NCHRP PROJECT 25-23, ENVIRONMENTAL INFORMATION MANAGEMENT AND DECISION SUPPORT SYSTEM

The objective of the first phase of NCHRP Project 25-23 was to develop a concept for an EIM&DSS that can serve all levels of decision making—planning, programming, project development, operations, and maintenance—and all modes of transportation. Figure 2 provides a useful view of the EIM&DSS in the form of a series of layers that are divided into two groups, one that supports environmental information management (EIM) and one that is a decision support system (DSS).

**Location Reference System and Geographic Information System**
The foundation for the EIM&DSS consists of linear and coordinate location reference systems and a geographic information system (GIS) tied to a relational database management system.

**Computer-Aided Design and Drafting System and Object-Relational Database**
Built on top of the location referencing system and the is a computer-aided design and drafting (CADD) system and a database that stores digital objects such as imagery, plan sheets, video, three-dimensional drawings, and virtual reality files.

**Content Management System and Metadata**
The next layer up is a content management system including metadata, which should be defined hand in hand with establishment of the EIM database. The metadata provide information about each important type of data in the EIM&DSS. Metadata include descriptions of the data, the time period to which it pertains, the source of the data, the individual responsible for maintaining the data, the geographical coverage of the data, and the completeness, accuracy (precision), and

statistical confidence of the data. Metadata might also include the types of devices on which the data can be displayed (e.g. desktops, laptops, and certain types of personal digital assistants).

**Environmental Information Management System**

In conjunction with a content management system goes a set of relational database tables that comprise the EIM system. The entity-relationship diagram (logical data model) developed under NCHRP Project 25-23 lists many attributes corresponding to each database entity (relational database table). Some of the important types of functionality that database tables support are

- The ability to track compliance with respect to commitments made regarding environmental stewardship initiatives, as well as with respect to formal policy, legal, or regulatory requirements.
- The ability to identify all transportation, environmental, social, economic, and cultural influences associated with any point, line, or boundary that can be identified in a GIS.
- The ability to establish stakeholder interests in different environmental, social, cultural, and economic factors for different levels of decision making (planning, programming, project development, operations, and maintenance) and the ability to develop a corresponding public involvement plan.

**Communications and Data Sharing**

The minimum requirement for data sharing is that relational databases need to have open database connectivity and there need to be telecommunications connections such as T1 lines, 800-megahertz system, ISDN, Virtual Private Network, and TCP/IP.

**Workflow Management System**

This layer consists of software that allows one to diagram a business process flow and to orchestrate the process in a manner that brings it to life. For example one might diagram the business process for the National Environmental Policy Act of 1969 (NEPA) and replace steps involving manual approvals and signatures with electronic approvals and signatures.

**System Integration—Environmental and Transportation Models and Simulation**

The EIM&DSS concept calls for extensive integration of environmental and transportation models. These models include simulation, optimization, multi-attribute utility analysis, and other procedures that enable managers, analysts, and external stakeholders to assess choices and tradeoffs, forecast transportation and environmental future outcomes, and allocate limited funding among competing needs.

**Decision Support**

Decision makers want the right information at the right time at the right place in the right format attuned to the context and audience in which a decision will be made. The EIM&DSS provides decision makers with a matrix of outcomes, outputs, and inputs (dollars, land, labor, equipment, and material) for each alternative or scenario under consideration. In other words, the EIM&DSS provides the capability to identify the full range of transportation, environmental, social, economic, and cultural impacts associated with any set of alternatives or scenarios pertinent to any mode and any level of decision making—planning, programming, project development, operations, and maintenance.

### Best Management Practices

The EIM&DSS has the capability of providing the user with information on best management practices (BMPs). These BMPs may consist of practices that are legally required or specified in regulations. They may also be practices determined to have the most beneficial impact based on comparative studies or benchmarking of different organizations. There are a variety of ways to communicate best practice information including a document depository, computer-based training, and expert advice.

### Presentation and Display: Collaborative Decision Making

The EIM&DSS concept supports collaborative decision making that involves both an agencies' key internal decision maker and external stakeholders. This type of decision making might occur in a "design tent" or at a public hearing. Collaborative decision making in real time represents the ideal type of decision making because all important decision inputs would be brought to bear almost instantly. This means that all the lower levels of the EIM&DSS functionality are brought to bear including the ability to access information in a GIS, a CADD, and relational database; the ability to draw upon any management system or simulation model that is relevant; the ability to bring the appropriate array of performance measures (outcomes, outputs, inputs) before decision makers; and finally the ability to display the impacts for each alternative in the most attractive and meaningful way.

## RESEARCH NEEDS REGARDING DATA AND INFORMATION MANAGEMENT

Each of the functional capabilities of the ISO 14001 compliant EMS and the EIM&DSS presented earlier imply specific data or information management needs. The remainder of this paper identifies some of the most important research needs.

### Need for a Performance Measurement Framework

The ISO 14001 standard uses a performance-based approach to continuous improvement that needs to work within DOTs and metropolitan planning organization (MPO) operating procedures. Data collection for an ISO 14001 system should not begin until an agency has established a framework for performance measurement and monitoring. Although countries outside the United States have developed EMS compliant with ISO 14001, few state DOTs and MPOs have. Consequently there is a need for research that would establish a performance measurement framework that can guide data collection. The research should address the following:

- The degree to which both transportation and environmental issues must be addressed and the extent that environmental issues include social, economic, and cultural impacts.
- The extent to which measures should address pollution prevention, reuse, recycling, waste reduction, and repair of facilities and equipment.
- Whether the performance measurement framework should employ a hierarchy of measures, namely economic value added, outcomes, outputs, and inputs.
- The extent to which outcome measures should be customer-oriented. Customers can be classified according to whether they are (*a*) users of transportation facilities, (*b*) individuals and businesses that pay taxes or user fees, and (*c*) those affected by spillover effects; for example,

owners of homes and businesses along a highway right-of-way that experience noise from vehicles using the road.

- Whether the measurement system should use a "balanced scorecard" involving four categories of measurement: customer, internal, financial, and learning and innovation.
- Whether the performance measurement system should build on other measurement systems being developed or implemented in an agency, including other performance-based planning efforts, public accounting procedures mandated by the Governmental Accounting Standards Board, and benchmarking procedures such as that being developed under NCHRP Project 14-13.

**Research on Content Management**

The most basic data and information management issue is that an effective approach to content management is required. Research on various approaches to content management of environmental data would be a very productive topic. Content management must address all issues regarding the management of data over its life cycle including analyzing the benefits relative to the costs of data collection, properly defining metadata, data acquisition, data storage, data updating, data retrieval, data sharing, and data deletion. A related issue is data security throughout the entire life cycle of data.

**Research on a Domain Specific Markup Language Using Extensible Markup Language**

Data exchange in the Internet era can be facilitated using Extensible Markup Language (XML). The XML standard is based on the Standard Generalized Markup Language that was also the basis for the widely used Hypertext Markup Language. In XML you can define a permissible syntax for communicating data, read an XML document using a parser, and develop standard data formats for a group of users or use data schemas based on a logical data model (entity relationship diagrams). XML is becoming the *lingua franca* of data exchange in the Internet era. Communities focused on information exchange, such as those involved in business-to-business commerce and business-to-government commerce frequently adopt a domain-specific version of XML; that is, a document-type definition customized for a particular application or market. A domain-specific markup language has already been established for communicating GIS coverages. However, the benefits of having a domain-specific markup language for exchanging all of the different types of data needed for an EIM&DSS goes far beyond what a markup language for geographic information offers.

Research is needed to define a domain-specific markup language for sharing the following types of data:

- For each alternative or scenario under consideration, an array of performance measures (value added, outcomes, outputs, inputs) involving all relevant transportation, environmental, social, cultural, and economic factors;
- Results of running various types of models, including transportation and environmental simulation and optimization models;
- Information that is entered into a public involvement plan including concerns of all key stakeholders;
- Information regarding compliance with stewardship commitments and commitments dealing with policy, legal, and regulatory compliance;
- GIS thematic maps; and

- Environmental and transportation assets located along each link of transportation networks and also at points of intermodal transfer.

**Workflow Management**

Both the ISO 14001 framework and the EIM&DSS imply a need to document environmentally related business processes. There is a need to document workflow step by step including decision points. Many existing business processes that involve extensive numbers of approvals can potentially be redesigned to accommodate electronic approvals, thus streamlining and speeding up the process. There is a considerable amount of commercial software available to document and help automate certain business processes. One major software vendor offers a product that allows one to document business processes using widely used diagramming tools and then orchestrate electronic processes, for example business-to-business exchanges. There is a need to conduct research regarding how workflow management tools can best enhance EMS.

**Best Management Practices**

Important content of an EMS are BMPs. Arising from an impulse of environmental stewardship, there is a growing recognition of the value of BMPs. A consensus has emerged that by pursuing and implementing BMPs it is possible to enhance and protect the environment and do it not because it is legally required but because it is the right thing to do. Laws and regulations reinforce the need for BMPs. To develop content on BMPs for EMS, there is a need for a series of 15 to 20 research studies on BMPs dealing with particular topics. Each of these research studies need to address a specific environmental, social, economic, and cultural issue and address each level of decision making (planning, programming, project development, operations, and maintenance). BMPs should not be developed just once; they need to be periodically updated. For example, approximately 5 years ago NCHRP funded the Synthesis study, entitled *Best Management Practices for Environmental Issues Related to Road and Street Maintenance.* This study, although full of good ideas, is already becoming out of date.

**Matrices of Environmental Impacts**

The EIM&DSS developed under NCHRP 25-23 includes the capability to access models and matrices (look-up tables) that would provide analytic results for a certain type of environmental impact. These matrices are merely a concept. To realize the concept, research is required to develop the matrices. Matrices of this sort could potentially be developed for dozens of different environmental and other impacts. For example, a matrix could be developed that would describe the environmental impacts of doing bridge deck overlay work on structures that span different types of streams and rivers.These matrices would be useful in providing preliminary impact analysis, perhaps appropriate to the planning or programming stage or for purposes of establishing that a certain action is a categorical exclusion. If the matrices are done well, they may also be useful for more detailed analysis.

## SUMMARY

Together, the ISO 14001 standard for EMS and the concept for an EIM&DSS developed under NCHRP Project 25-23 imply a variety of data and information needs. These systems will not be effective and it will not be possible to maintain them unless ample effort and resources are devoted to gathering appropriate data and having an effective content management system. Certain types of data or information need to be compiled for these EMS, for example matrices of impacts, and best management practices. Content management ought to include procedures for assessing the benefits of the data relative to the costs of collecting it. Also it is essential to have metadata that covers the entire life cycle of each important type of data. In the Internet era, to facilitate data sharing, much metadata ought to be embodied in a domain-specific XML format. These ideas are fundamental issues related to the management of environmental information. There are significant gaps in knowledge regarding each of these needs; therefore, they represent areas ripe for research.

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**FIGURE 1 Required elements of the ISO 14001 Standard for Environmental Management Systems.**

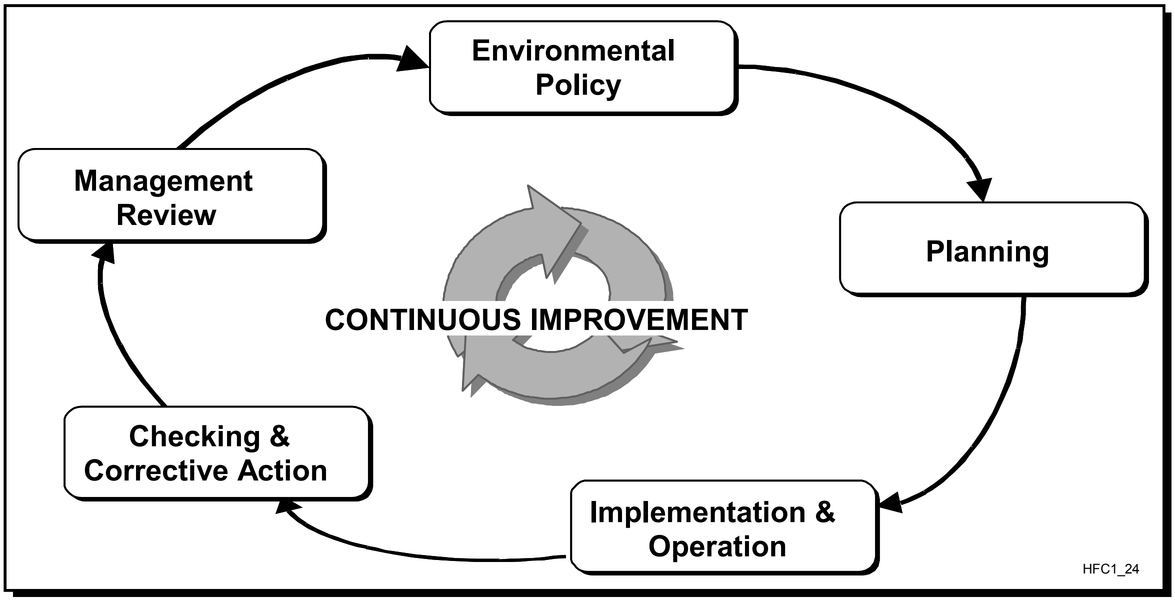
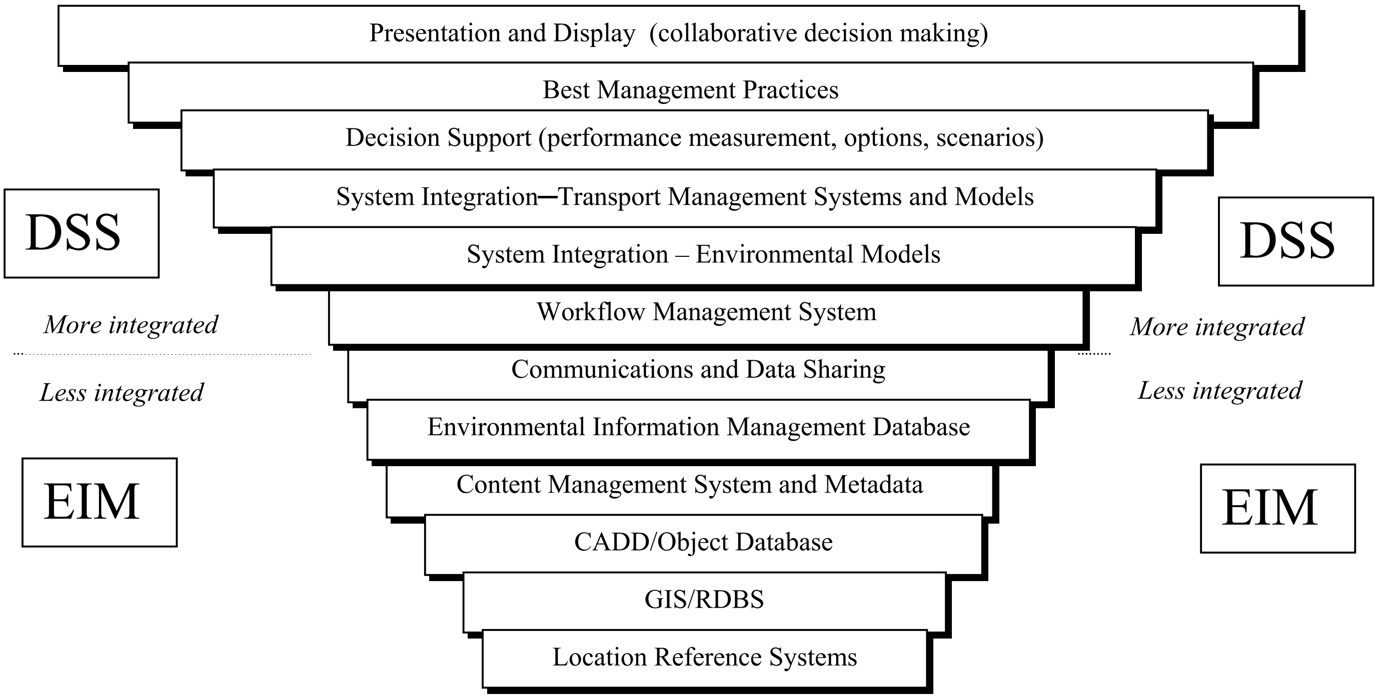


**FIGURE 2 Layers of the NCHRP Project 25-23 EIM&DSS**



RESEARCH NEEDS STATEMENTS

# Environmental Information Management

### 1. Best Practices for Collection, Distribution, and Maintenance of Environmental Resource Information

**Problem Statement**
Transportation agencies across the nation use an abundance of environmental resource information to support transportation decision making. The collection, maintenance, and distribution of this information can be costly. Opportunities for cost reduction are lost when data are collected on a project-by-project basis or made available solely through hard-copy reports. Transportation agencies can benefit by exchanging information about successful methods for managing environmental information in support of transportation decision making.

**Proposed Research**
Review current and emerging practices used by transportation agencies throughout the nation to collect, maintain, and distribute environmental management information. Identify those practices that have proven to

- Reduce costs to individual agencies,
- Enhance information sharing within and among agencies, and
- Improve access and ease of use by transportation professionals and the public.

Research should address all issues regarding the management of data over its life cycle, including techniques for data collection, properly defining metadata, data acquisition, data storage, data updating, data retrieval, data sharing, data deletion, and data security. Identify software applications that improve the distribution of environmental data by making the information easier to use and understand. When reviewing data collection methods, include emerging technologies such as remote sensing and advanced field data collection techniques (i.e., voice recognition, pen-based computer, global positioning system, and digital camera/video). Also, include recommendations for exchanging environmental and transportation information using a standard markup language, such as Extensible Markup Language (XML) or other procedures that allow people to have a window into databases found throughout distributed systems.

When complete, provide the list of best practices on a searchable, web-based application. Provide recommendations for the annual review and maintenance of the list.

**Cost:** $250,000
**Duration:** 18 months

### 2. Identifying Critical Environmental Information for Transportation Systems

**Problem Statement**

Environmental information and its usefulness are diverse and distributed among many entities. There is no clear guidance or direction as to what are the most appropriate and critical types of environmental information, nor is there any guidance on the identification of sources of environmental information for use at various stages of decision making regarding transportation systems. A review of the various types and sources of environmental information for use throughout the development of transportation improvements would be a valuable resource. This information could guide the transportation professional on the allocation of resources to help identify and obtain the most critical environmental information for use in performing the appropriate environmental reviews, assessing potential impacts, and monitoring environmental resources.

Inquiry into the availability of critical environmental information would support several other environmental research initiatives such as Streamlining and Environmental Stewardship, Integrated Environmental Decision Making, and potentially any specific environmental area.

**Proposed Research**

Develop a team of experts to identify environmental information requirements for all major phases of transportation development. This will include the identification of information pertinent to the planning phase, the environmental review (NEPA) phase, and the design, construction, operation, and maintenance phases. This effort will include providing recommendations regarding accuracy and level of detail required, as well as assessing the availability of this information for different types of analysis at different points in the process. Sources of information will be identified including information maintained or available through other entities, as well as environmental information on and within transportation corridors for the purpose of asset management. The identification of information will also consider environmental information used in performance measures linked to standard best business management practices for implementing environmental management systems.

The identification of environmental information should encompass all environmental areas. Among the examples of information to be identified are the physical environment, including geological and geographic features; natural environmental features consisting of habitat and ecosystem information; and social or demographic information.

The research effort consists of reviewing several states to assess the type of environmental information available. A matrix could be developed showing the types of information, its sources, and the transportation development phase for which it is most relevant.

**Cost:** $250,000
**Duration:** 24 months

### 3. EVALUATION OF ENVIRONMENTAL MANAGEMENT SYSTEM IMPLEMENTATION FOR TRANSPORTATION AGENCIES

**Problem Statement**

Although countries outside the United States have developed environmental management systems (EMS) such as the International Standards Organization (ISO) 140001, few transportation agencies have been certified or implemented an EMS. Private industries across the United States have found that implementing an EMS is effective in reducing costs, improving operations, and enhancing industry image, which benefits both investors and customers.

Consequently, there is a need for research that would evaluate the costs and benefits of an EMS for the transportation industry. There is also a need to establish a performance measurement framework that can guide data collection to support EMS.

Transportation agencies find it difficult to measure environmental performance due to the lack of data associated with environmental procedures. There is a need for performance measurement standards with regards to environmental information throughout planning, project development, construction, and maintenance operations. An EMS would facilitate environmental stewardship, support environmental streamlining through programmatic agreements and process improvement, and establish performance measures based on a transportation agency's goals and objectives.

**Proposed Research**

Review up to three transportation agencies/entities, including a state department of transportation's (DOT's) and transit agency's current environmental policies, procedures, programs, and systems and compare them with the criteria for an EMS such as the ISO 14001 protocol. The analysis should identify the common needs for transportation agencies to implement an EMS, such as ISO 140001. Results should address the costs and benefits of implementation including certification and maintenance, qualitative and quantitative elements of implementation, and ongoing performance improvement.

**Cost:** $400,000
**Duration:** 24 months

### 4. INTELLECTUAL PROPERTY RIGHTS FOR ENVIRONMENTAL DATA AND INFORMATION

**Problem Statement**

A potentially major barrier to sharing data in environmental and related management systems is intellectual property rights, including copyrights, licensing, and terms of use. Although state DOTs generally try to keep information they acquire in the public domain, they still maintain ownership over data and, in certain cases, may impose restrictions on the use of environmental data. Sometimes there are circumstances where use of the data by others could be detrimental to the state's interest or harm individuals or businesses. Also, if the state enters into a partnership with other organizations, educational or private, depending on the objectives of the partnership, the state may wish to maintain control over the use of the data. For educational applications, there is generally a strong presumption that the data should be free and widely available. Indeed, if DOTs purchase data with state or federal dollars, then these data should be available to other organizations. However, for a public/private partnership that is expected to earn revenues and potentially make a profit, the principle of willingness to pay would govern the ability to use the data. Another important issue to consider is that potential users of the data will use a peer-to-peer file sharing website, in the same manner that some people share and download copyrighted music files. Violation of copyrighted environmentally related information could potentially be an anathema to owners of copyrighted material, just as it has been to the music industry.

**Proposed Research**

The objective of the research would be to examine alternative approaches to the management of intellectual property rights regarding environmental data and information. The main issue is under what circumstances should environmental information and data be provided free of charge. Circumstances to examine include acquisition and use of data by states and MPOs, partnerships with educational institutions, and public/private partnerships. The study should address intellectual property rights including but not limited to copyrights, licensing rights, and terms and conditions of the use of websites. This study should also address the appropriateness of peer-to-peer file sharing procedures to allow users of environmental data and information to share files at no cost.

**Cost:** $150,000
**Duration:** 15 months

### 5. EXTEND ASSET MANAGEMENT SOFTWARE TO INCLUDE ENVIRONMENTAL ASSETS

**Problem Statement**
DOTs use asset management to exercise effective stewardship of the public assets for which they are responsible. For example, pavement and bridge management systems (PMS and BMS) are used to help manage the pavement and structures of roads. Presently, these tools fail to include environmental assets for which the DOTs are responsible. In highway rights-of-way (ROW), there are environmental resources such as vegetation, habitat, and noise berms/barriers. Additional environmental assets exist outside of the ROW, such as retention ponds and maintenance sheds. DOTs could benefit from tools that help manage these environmental assets.

**Proposed Research**
Develop a team of experts and potential stakeholders including DOTs, environmental agencies, researchers, and citizen groups to

- Inventory the types of environmental assets controlled by a typical DOT for which data are conveniently available.
- Evaluate and rank each type of data in respect to its utility for environmental asset management.
- Develop decision matrices (look up tables) that describe the environmental impacts of different treatments in transportation management systems, including but not limited to Pavement Management Systems (PMS), Bridge Management Systems (BMS), Highway Economic Requirement Systems, and ROW management systems.
- Evaluate existing asset management systems, such as PMS, BMS, and ROW management systems, and determine which ones might be enhanced to accommodate environmental asset management.
- Develop a detailed design for a parallel software application that includes environmental asset management. Alternatively, negotiate with software vendors to incorporate environmental asset management requirements into existing systems.
- Develop a pilot application in at least one state to test the concept of integrating environmental stewardship into asset management.

**Cost:** $650,000
**Duration:** 24 months

## 6. Resource Allocation for Managing Environmental Data and Information

### Problem Statement

Among the most challenging issues faced in environmental management, including the implementation of EMS, is collecting the required data and information and assuring that the value of the information exceeds the costs. Without a well-thought-out approach that takes into account the costs and benefits of having the data and information over its life cycle, there is a high probability that the information will not be widely used, will not have the accuracy and coverage required, and will not be updated and maintained. Consequently, the EMS is put at grave risk of failing.

To solve these problems there needs to be a programmatic approach to the life-cycle management of data and information that attempts to allocate limited funds by weighing the life-cycle benefits and costs of each major type of environmental information and data.

Information should not be collected unless its value exceeds the costs. Also, if it is determined that there are not enough funds to collect a certain type of information but the value greatly exceeds the costs, then it should be possible to make a strong case to top management to provide additional funds to acquire the environmental data.

### Proposed Research

The research is to develop procedures and guidelines to help transportation agencies better manage environmental data and information over its life cycle. These procedures and guidelines should be based on an appropriate level of detail and structured to help transportation agencies set priorities and allocate resources for data acquisition, preparation of metadata, storage, updating, and disposal. The procedures and guidelines would be tested in five organizations (states and MPOs), representative of others throughout the country. The researcher would be required to explore a variety of different criteria for assessing the value or worth of each type of data relative to the costs. Also, the researcher would develop alternative criteria for prioritizing how limited funds could be applied to manage essential environmental data and information. It is desirable that top management in each agency participate in the process and oversee the allocation of funds as well as any increases or decreases in funds for gathering, updating, and managing environmental information over its life cycle.

**Cost:** $400,000
**Duration:** 24 months

## 7. Evaluate and Extend the Florida Efficient Transportation Decision-Making Process (Streamlining) for Use in Other States

### Problem Statement

Most transportation/environmental analyses and approvals are paper-based operations. Consequently, most analyses fail to capitalize on modern information technologies for analysis, tracking, and communication for effective transportation environmental solutions. Similarly, communications with other stakeholders are constrained by the ability to move and evaluate information. In addition, the current system lacks accountability and transparency. The Florida Efficient Transportation Decision Making (ETDM) system seems to have solved many of these problems and should thus be evaluated, improved, and extended for potential application in other locations.

**Proposed Research**

The proposed research will be conducted in two phases:

Phase I. Organize a team of experts and potential stakeholders including DOT's, environmental agencies, researchers, and citizen groups to

- Identify and evaluate the principle components (including data, applications development, hardware, personnel, interagency procedures, and agreements, etc.) of the Florida ETDM system.
- Identify and evaluate potential extensions of the model for improving its utility.
- Develop recommendations for implementation in other states, including costs.

Phase II. Based on the recommendations from Phase I, pilot and implement the system in a number of states.

**Phase I— Evaluation Cost:** \$250,000–\$300,000
**Duration:** 12 months
**Phase II—Pilot and Implementation Costs:** \$2,500,000

# Environmental Streamlining and Stewardship

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RESOURCE PAPER

# Environmental Streamlining and Stewardship

James Bach, *Louis Berger Group, Inc.*
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Environmental streamlining and environmental stewardship represent two of the fastest-growing forces in the transportation field. Although the impetus for each movement is different, they have a unified goal: better transportation decisions and a healthy human and natural environment. An increasing number of transportation professionals identify a critical link between the two topics. They believe that effective environmental streamlining will occur only through the demonstration of environmental leadership by transportation agencies, and that environmental stewardship is a key component of environmental leadership (Codell 2001).

Environmental stewardship in transportation, in its most fundamental terms, is the effective management and protection of the natural and human environment through informed decision making about transportation projects and programs. For some, this translates into ensuring that transportation agencies avoid, minimize, and mitigate the environmental impacts from transportation. Others extend their vision of stewardship to include taking advantage of opportunities to enhance the environment, or to reverse past adverse environmental effects, through transportation. A number of state transportation agencies already incorporate stewardship efforts as an integral part of their transportation project planning, development, construction, maintenance, and operations. Other agencies are initiating efforts to incorporate stewardship in transportation.

Environmental streamlining is the term given to efforts, spearheaded by the U.S. Department of Transportation (DOT), to improve transportation project delivery and enhance environmental protection by means of improved interagency coordination. A primary tool for environmental streamlining is the use of cooperative agreements among agencies holding approval, review, and/or permitting jurisdiction over a particular project. These agreements enumerate project-related expectations among agencies, including time frames for required review and permit procedures. Because major transportation projects typically involve agencies at the federal, state, and local levels, improved interagency cooperation is critical to the success of environmental streamlining.

Although current streamlining efforts are driven by the requirements of the Transportation Equity Act for the 21st Century (TEA-21, P.L. 105-178) of 1998, the concept of streamlining environmental review procedures is not a new idea. The Council on Environmental Quality (CEQ) is implementing regulations (CEQ, 40 CFR Parts 1500–1508, 1978) for the National Environmental Policy Act of 1969 (NEPA, P.L. 91-190) directing agencies to engage in cooperative consultation, integrate the NEPA process into early project planning and review activities, identify significant issues early in the process, and place appropriate time limits on the environmental impact statement (EIS) process (CEQ, 40 CFR Parts 1500–1501).

## ENVIRONMENTAL STREAMLINING

### NEPA and Project Development

The environmental review process required under NEPA has long been the object of criticism because of the perception that it causes unnecessary delays in the overall development of highway and transit projects. This perception increases when an EIS, the most comprehensive level of documentation required under NEPA, is prepared for a project. If required on a given project, the reviews undertaken pursuant to other federal regulations such as Section 4(f) of the Department of Transportation Act, Section 7 of the Endangered Species Act, and Section 106 of the National Historic Preservation Act may also contribute to delays in overall project development. Given that these regulations and procedures are generally addressed during the NEPA process, the perception of NEPA as the cause of delay may be exacerbated.

Despite its pervasiveness, the perception that NEPA causes delays in overall project development is often based on anecdotal evidence from individual projects. In 2001, to provide a more accurate understanding of the effects of the NEPA process, the Federal Highway Administration (FHWA) released a study examining the true schedule implications that the NEPA process had on the total project delivery process and the individual factors influencing the amount of time required for the NEPA process for individual projects.

The study results indicated that over the 30 years since the inception of NEPA, the average time to complete an EIS for a transportation project was approximately 3.6 years. By comparison, the mean length of time for the completion of the project was approximately 13.1 years. Completion of the NEPA process accounted for approximately 28% of the overall time for project development. The study also made a decade-by-decade comparison of the time required to complete an EIS. The mean time for completion of an EIS in the 1970s was 2.2 years, whereas in the 1980s and 1990s, EISs were completed in 4.4 and 5.0 years, respectively (*Evaluating the Performance* 2001).

## TEA-21 and Streamlining

### *TEA-21*

Responding to the concerns over delays in transportation project development, TEA-21 directs the U.S. DOT to streamline procedures related to the environmental review of highway projects undertaken pursuant to NEPA. Specifically, Section 1309 of TEA-21 directs the U.S. DOT to develop and implement a coordinated environmental review process by which the U.S. DOT would work with other federal agencies to advance major highway projects requiring EISs or environmental assessments. This coordinated process is to include

- Identification of all potential federal agencies with jurisdiction over a project, including those with NEPA responsibilities, as well as other federal agency environmental analyses, reviews, opinions, permits, licenses, and approvals.
- Establishment of cooperatively determined time frames for project review milestones.
- Use of concurrent reviews (as opposed to sequential) to save time.
- Use of a memorandum of understanding incorporating these elements of the coordinated process.

In addition, Section 1309

- Allows the states the option of including state-mandated environmental reviews in the coordinated environmental review process.

- Establishes a dispute resolution process between the U.S. DOT and other federal agencies.
- Allows states to transfer a portion of their federal aid to reimburse federal resource agencies for staffing expenses associated with meeting expedited time frames.

***National Memorandum of Understanding***

In July 1999, the U.S. DOT and other federal agencies[1] involved in environmental permitting and processes entered into an Environmental Streamlining National Memorandum of Understanding (MOU) (*Environmental Streamlining Memorandum* 1999). The National MOU commits the signatory agencies to implementing Section 1309 of TEA-21 for highway and transit projects using a broad strategy for reducing project delays and protecting and enhancing environmental quality. Highlights of this strategy include identifying solutions to reduce unnecessary project delays, early identification and resolution of issues, concurrent review of projects, the development of procedures for dispute resolution, and the establishment of goals, performance measures, and benchmarks to evaluate transportation and environmental decision making. The National MOU also encouraged support for agency field offices as they explore flexible streamlining opportunities on their own and with state partners.

***Action Plan***

The Environmental Streamlining Action Plan guides the implementation of the National MOU by defining individual agency commitments and specific target activities to advance streamlining. The Action Plan focuses the federal streamlining initiative on its singular goal: *reduce transportation project delays while enhancing and protecting the environment*. To achieve this goal, the Action Plan outlines the following strategies:

1. Establish timely, and where feasible, concurrent project reviews. This requires active and rigorous coordination among federal, state, and local partners through early, sustained, and continuous involvement of federal and state resource agencies.
2. Avoid environmental impacts where possible and use compensation, regionwide, areawide mitigation activities advanced by improved data inventories and the development of programmatic agreements.
3. Negotiate formal agreements among state and federal partners. Allocate resources to support early involvement, adequate staffing, interagency training, and information dissemination requirements through mutually agreed upon interagency priorities.
4. Keep projects on schedule through the use of conflict avoidance and resolution practices.
5. Measure continuous improvement and progress through best practices and evaluation techniques such as benchmarking performance standards. Modify approaches to streamlining based on results.

Each of these five strategies is supported by specific implementation actions, designated lead agencies, and target dates. The scope of the implementation actions varies from the “global” level—for example, all federal agencies were responsible for establishing key streamlining contacts in each of the federal resource agency field offices and national offices by

[1] The other signatories to the National MOU are the U.S. Army Corps of Engineers, U.S. Department of the Interior, U.S. Environmental Protection Agency, U.S. Department of Commerce, Advisory Council for Historic Preservation, and U.S. Department of Agriculture.

March 2000—to the "project" level; for example, the U.S. Fish and Wildlife Service is responsible for identifying migratory bird species and other resources affected by projects early (*Environmental Streamlining Revised Draft* 2001).

**Implementation**

The U.S. Congress, U.S. DOT, other federal, state, and local agencies, and transportation industry groups have been working on a number of fronts to further the streamlining requirements of TEA-21 through national activities, interagency activities, regulatory initiatives, oversight and funding, and pilot projects.

***National Activities***

The broader streamlining activities in the Action Plan are being implemented by the U.S. DOT through the FHWA's Office of NEPA Facilitation, concentrating on a set of priorities referred to as the National Areas of Focus: National Leadership, Coordinated Strategies and Effective Communication, Training/Technical Support, Alternative Dispute Resolution, and, Performance Measures. Important activities to date include the updating of FHWA's environmental streamlining Internet home page, complete with a monthly "Successes in Streamlining" newsletter showcasing projects that have incorporated streamlining measures. The U.S. DOT is also developing a conflict management and dispute resolution system that includes providing guidance to agencies for resolving disputes in the project development process, training courses focused on effective problem solving and collaboration skills, access to qualified third-party mediators, and procedures for elevating disputes to the secretary of the U.S. DOT when necessary. A further initiative is the FHWA's development of performance measures and best practices through a series of quantitative and qualitative studies of the NEPA process including factors influencing project delays and cost increases. The first such study, Evaluating the Performance of Environmental Streamlining: Development of a NEPA Baseline for Measuring Continuous Performance, was completed in 2001 (*Evaluating the Performance* 2001).

***Interagency Activities***

Other activities outlined in the Action Plan are being implemented at the regional, state, and project levels. Although the overall level of participation in environmental streamlining varies by individual state, all 50 states are involved in some type of streamlining activity. An overview of these activities follows.

- Thirty-three states have interagency agreements that provide for state funding of personnel at federal and/or state resource agencies. Such agreements facilitate the funding of dedicated review staff positions, thereby reducing the financial constraints as an issue for resource agencies. The funding by states (using federal-aid funds) for activities that expedite project reviews undertaken by federal agencies is allowable under Section 1309 of TEA-21. The FHWA is finalizing nonregulatory guidance for states involved or interested in such arrangements. The guidance, which is expected to be available shortly, includes templates for personnel agreements and an assessment of lessons learned by states that have used such funding agreements.
- Twenty-three states have interagency agreements with resource agencies to merge the NEPA and Section 404 (Clean Water Act) compliance processes. This number is up from just six states a few years ago. Although the concept of merging NEPA and Section 404 predates

TEA-21, such agreements have gained momentum in recent years. Many have been finalized or updated to reflect streamlined processes.

- Twenty-eight states have interagency agreements concerning Section 106 (National Historic Preservation Act) compliance. Such agreements may involve excluding from state historic preservation offices (SHPOs) the review of certain routine projects that have minimal or no impact on historic properties, or delegating the responsibility to initiate consultation with the SHPO from FHWA division offices to the states. In all states, such agreements allow resources to be devoted to addressing major issues. In some states, programmatic agreements have decreased the workload of the SHPOs and state DOTs on minor projects by 90%.
- Fifteen states are engaged in initiatives or agreements with Native American tribes. These agreements provide for enhanced consultation and coordination on a variety of issues, particularly cultural resources/Section 106 review.
- Thirty-five states are engaged in initiatives or agreements related to the streamlining of required review and other processes. These include regional MOUs among states and federal resource agencies and state-level agreements for integrated planning and environmental decision making. Prominent among these are Florida's Efficient Transportation Decision Making Process and Oregon's Collaborative Environmental and Transportation Agreement for Streamlining, both of which are aimed at better integration of the planning and NEPA processes (personal communication, L. Garliauskas, FHWA, Jan. 4, 2002).

***Regulatory Initiatives***

On May 25, 2000, the FHWA and Federal Transit Administration (FTA) jointly proposed regulations for NEPA and Related Procedures for Transportation Decision-making, intended to replace the existing NEPA regulations found at 23 CFR Part 771. The proposed rule provided for the establishment of a streamlined environmental review process for highway and transit projects. Specific elements of the proposed process include early consultation and coordination among federal agencies and the documentation of these efforts; agency concurrence at the close of the scoping process, including required reviews and approvals; issues to be addressed; issues eliminated from consideration; methodologies, processes; and schedules. In the event of disagreements among agencies during NEPA, the proposed regulation directs FHWA/FTA to initiate a dispute resolution process as outlined in TEA-21. The proposed regulation includes provisions for reducing paperwork and removes the requirement for a coordinated process for projects not requiring an EIS. Finally, the proposed regulation provides for the inclusion and coordination of state environmental reviews with federal processes (*NEPA and Related Procedures* 2000).

Congress, as well as transportation industry groups, commented that the proposed regulations fail to address the streamlining provisions of TEA-21. During oversight hearings held by the 106th Congress, some members of the House and Senate were critical of the proposed regulation for not requiring concurrent reviews, cooperatively determined time frames, and a dispute resolution mechanism. The American Association of State Highway and Transportation Officials (AASHTO) and the American Consulting Engineers Council issued similar comments (*Joint AASHTO–ASEC Statement* 2000). The FHWA responded by stating that it would evaluate all comments when developing the final regulation.

The Clinton Administration did not issue a final rule and it is unclear what action the Bush Administration will take. At a "Washington Briefing" held by AASHTO in February 2001, Cynthia Burbank, FHWA Program Manager for Planning and Environment, outlined several options for the new administration. These included issuing final rules based on the comments already received, starting over and issuing a new proposed rule, or deferring rulemaking altogether and proceeding with work on reauthorizing TEA-21, which expires on September 30, 2003 (Congressional Research Service 2001B).

***Congressional Oversight***
The House Committee on Transportation and Infrastructure and the Senate Committee on Environment and Public Works each held hearings in 2001 at which the FHWA's efforts to implement the streamlining provisions of TEA-21 were examined. As noted previously, some members expressed concerns over the inadequacies of the proposed regulations. Once the regulations are finalized, the pace at which they are applied on a national scale and their overall effectiveness will likely be examined. Furthermore, how the National MOU will work in tandem with the streamlining regulations to fulfill the requirements of TEA-21 may be a topic for congressional oversight as well. A potential issue regarding the pilot projects now underway (see following section) will be whether the knowledge gained from such experiments will prove too limited in scope or applicable to many different types of highway projects on a larger scale. Although no specific streamlining-related legislation has been introduced thus far in the 107th Congress, the Department of Transportation and Related Agencies Appropriations Act for FY 2002 (P.L. 107-87), signed by President Bush on December 18, 2001, includes $1.5 million for the FHWA's streamlining activities (Congressional Research Service 2001A; Department of Transportation 2001).

***Pilot Projects***
In July 2000, 10 transportation projects in 7 states were selected for participation in a pilot program jointly sponsored by the FHWA, Environmental Protection Agency (EPA), and AASHTO. The purpose of the pilot program is to examine effective and efficient ways to implement the environmental streamlining requirements of TEA-21. Federal and State officials established the program to gain practical experience in streamlining the environmental review process before applying it on a larger scale (Congressional Research Service 2001A). Projects were nominated by the states and have been accepted by the agencies as demonstrating innovation in environmental review and processing. The projects, currently in the implementation stage, include an endangered species habitat protection program in California, an intermodal port access corridor at the Newark/Elizabeth (New Jersey) Seaport and Airport, and a comprehensive rail passenger program in Georgia. Other states in the program are Florida, Oregon, Texas, and Wisconsin. The projects focus on various aspects of the environmental process, such as early coordination, integration of environmental concerns into the planning process, and the establishment of project-specific time frames (*EPA and FHWA Approve* 2000).

**Challenges**
Have the efforts of the U.S. DOT and other agencies achieved the desired goal of streamlining environmental processes and time savings for the project applicant and review agencies? Although it may be too early to pass judgment, there is some evidence to suggest that is the case. The FHWA's Office of NEPA Facilitation reports that the EPA's "lack of objection" ratings of FHWA EISs has improved from 35 to 40%. Also, the time to complete NEPA, from notice of intent to record of decision, has decreased by 6 months, from 6 to 5.5 years, over the last several years. In states with streamlining agreements in place and/or those states assisting the EPA by

providing dedicated review staff or travel funding, the number of comments and concerns has significantly decreased. Individual states have also reported time savings due to streamlining (personal communication, L. Garliauskas, FHWA, Jan. 4, 2002).

Participants at a recent Transportation Research Board (TRB) conference agreed that early resource agency involvement in the transportation planning process often leads to early conflict definition and resolution.In addition, the integration of transportation and environmental decision making by means of interagency agreements and MOUs can result in a reduction of time spent in pursuit of specific project approvals. Participants also noted that the benefits of better integration of watershed, transportation, and environmental planning include better designs, environmental sensitivity, overall cost savings, and resolution of real and perceived conflicts (Santore 2000).

The potential for improving and enhancing streamlining efforts exists at the federal, state, and local levels. Although states have been building efficiencies into their review processes, there has not been as much focus on establishing and adhering to specific time frames. One avenue of improvement would be to encourage some level of delegation by resource agencies to states for small and no-risk projects (e.g., screening, data collection, and inventories for evaluation). In particular, the U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) have entered into few programmatic agreements with states. An important challenge is getting the resource agencies to an appropriate level of comfort for them to yield some of their responsibilities to the states. It is also important to recognize that statutes (e.g., the Endangered Species Act), which govern FWS and NMFS procedures, are among the most restrictive when it comes to allowing administrative flexibility. The FHWA will soon be releasing guidance that clarifies existing flexibility available to FHWA and state applicants in delegated roles under informal consultation (personal communication, L. Garliauskas, FHWA, Jan. 4, 2002).

One approach may be for resource agencies to identify priorities among individual resources at a watershed or ecosystem level; for example, determine the relative quality of wetlands according to set criteria. States could use this classification system during the corridor-planning phase to identify resources as opposed to waiting until an alignment is sketched out and presented to the resource agency for review. States and resource agencies could then develop programmatic agreements wherein benefits would be derived on both the project side and resource side through avoidance, mitigation banking, or other approaches. Such arrangements raise further issues, such as how to quantify the benefits of wetland banking and crediting states for avoidance actions taken (personal communication, L. Garliauskas, FHWA, Jan. 4, 2002).

A further challenge is how to promote partnerships among agencies that involve some element of risk-taking to advance innovative approaches; for example, how to proceed when the potential for impacting a particular resource cannot be quantified because of inadequate data or the need for further study. Such innovative approaches would need to be tested for effectiveness and undertaken only if they incorporated evaluation measures. Again, resource agencies need to find an appropriate level of comfort by identifying impact thresholds and acceptable levels of risk. Mitigation could be based on available data, with contingencies built in for situations where a resource is discovered during construction (personal communication, L. Garliauskas, FHWA, Jan. 4, 2002).

Often, the biggest challenge in environmental streamlining is organizational. Matching institutional structure and procedural requirements with workload reality has proven difficult. The lines of communication between planners, policy makers, and field office staff are not always clear. Agency roles and responsibilities have evolved, but organizations have not. States and resource agencies need to reassess staffing patterns and resources according to day-to-day needs. Unfortunately, lack of funding and trained personnel are key barriers to substantial involvement by resource agencies in all but the most pressing of environmental issues (Santore 2000).

## ENVIRONMENTAL STEWARDSHIP

In contrast to the regulatory underpinning of the streamlining movement, environmental stewardship initiatives reflect an internally generated shift in the culture and business practices of transportation agencies. The strengthening of environmental values in transportation agencies is the result of agency perceptions that stewardship is "the right thing to do" and that it is a sound business practice within their state and its local communities.

Although stewardship is not a response to regulatory requirements, many leaders in the transportation area believe that a strong stewardship ethic will contribute to the streamlining of environmental review processes by building the reputation of transportation agencies as trusted and responsible partners in environmental protection (Mallory 2001). This belief is reinforced by the experience of many state transportation agencies with the widespread public and resource agency support for projects and programs that demonstrate sensitivity to environmental issues and have clear environmental benefits.

### Definition and Scope

Environmental stewardship is not a new concept, but only recently has its role in transportation become prominent nationally. As a result, transportation and environmental professionals are working to define the scope and meaning of environmental stewardship in transportation. A paramount effort in this area is the work of the TRB Committee on Environmental Analysis in Transportation (A1F02). The committee hosted workshops on environmental stewardship at the TRB annual meetings in 2001 and 2002. The first workshop focused on defining stewardship. The second workshop, cosponsored with the TRB Committee on Landscape and Environmental Design (A2A05), addressed the "next steps" for stewardship.

The A1F02 proceedings for the first session, *Workshop Summary—A "Work in Progress": Environmental Stewardship in Transportation Program Execution* (2001) captured the views of attendees on the scope and meaning of environmental stewardship in transportation. The definitions of environmental stewardship included

- Improving environmental conditions and the quality of life when possible, not just complying with regulations.
- Careful management of environmental resources and values through partnerships among public and private entities.
- Attitudes, ethics, and individual behaviors.
- Wise choices based on an understanding of the consequences to the natural, human-made, and social environment.
- Fulfilling responsibilities as trustees of the environment for succeeding generations and moving towards a cost-effective and environmentally sustainable future.
- Integrating environmental values as a "core business value" for transportation agencies and their partners.

The workshop attendees saw many opportunities for stewardship in transportation activities. They endorsed a broad vision in which the scope of environmental stewardship encompasses all transportation functions: planning, design, construction, operation, and maintenance. Considerations relevant to stewardship cover the full range of human and natural environmental concerns.

The workshop identified better transportation programs and services, improved public and regulatory agency attitudes towards transportation agencies, and achievement of TEA-21 streamlining goals as some of the benefits of stewardship. The workshop members discussed how transportation agencies could create a commitment to environmental stewardship. Critical steps include adoption of an agency-wide commitment to environmental excellence. Without it, the benefits of consistent quality in environmental performance will be elusive. Another element is the treatment of environmental costs as a legitimate cost of transportation infrastructure. The group also noted the need for sound environmental performance measures for transportation.

Perceived barriers to transportation agency success in environmental stewardship include

- An "us versus them" attitude between transportation and environmental professionals,
- Fear of precedent and implications for future transportation programs,
- Lack of available stewardship models and the resources to develop them,
- Perception that environmental enhancements cost too much and take too long,
- Compartmentalized organizational structures that isolate environmental responsibilities, and
- Narrow interpretations of transportation mission and the scope of "public safety."

## Implementation

### *2002 TRB Workshop*

The 2002 TRB workshop further developed the knowledge base in environmental stewardship by compiling information on stewardship needs and opportunities in planning, design, construction, maintenance, and operations. The proceedings for that event, *Workshop Summary— "Making It Happen": Next Steps for Transportation Environmental Stewardship Through Context Sensitive Planning, Design, Construction, and Maintenance* (2002), articulate the following common needs:

- Partnering agreements among state transportation agencies, environmental agencies, and the construction industry;
- Early and continuous involvement of environmental professionals;
- Education, outreach, training, and strategic planning;
- Use of environmental management systems to incorporate stewardship into all transportation agency activities;
- Implementation of a "buy green" procurement philosophy;
- Funding flexibility; and
- Public and internal recognition of environmental excellence on the job.

Workshop members identified specific needs within each of the functional areas. The extensive lists, available in the proceedings, create a menu of options for future stewardship activities.

The 2002 TRB Workshop discussions reinforced a number of widely acknowledged keys to success in environmental stewardship. One is leadership within the transportation agency. Through leadership, stewardship becomes an organizational priority, and cultural change occurs to support stewardship practices. The integration of stewardship into every day operations leads to proactive approaches. Planners, designers, construction personnel, and maintenance crews recognize and take advantage of opportunities to protect or enhance conditions in the human and natural environment. A second key is good data. Gathering and using accurate information, particularly in planning and design phases, facilitates decisions that are sustainable through the life of a project.

Public involvement also is a key to success. This applies to both natural and human resources. Public involvement helps to identify and address potential effects and potential enhancements that may otherwise be difficult for the transportation agency to ascertain.

Another key to success is increasing the understanding of the connections between the environment, land use, and transportation. Increased understanding will help foster the creation of more effective criteria and tools for the development and management of transportation systems.

***AASHTO Demonstration Program***

In 2001, AASHTO initiated a program to promote environmental stewardship in transportation. The AASHTO Environmental Stewardship Demonstration Program is designed to foster the sharing of information and best practices among the state transportation agencies. AASHTO established a website for the program (www.stewardship.transportation.org) to enhance the availability of information on stewardship and the demonstration projects.

As a part of the program, AASHTO developed a suggested framework for designing a stewardship program. The framework describes four potential approaches to environmental stewardship in transportation: adding features to individual projects, creating programmatic approaches covering multiple projects, promoting cultural and organizational change, and instituting environmental management systems. The AASHTO Environmental Stewardship Demonstration Program website offers a listing of sample activities within each of the four approaches.

As of February 2002, 17 states[2] had registered 24 demonstration projects. The participating states will report on their experiences over the next 2 years. The registered projects involve a wide variety of approaches, including

- Implementation of context-sensitive design (Wisconsin),
- Development of a memorandum of agreement for stormwater management (Tennessee),
- Adoption of a department-wide environmental ethic (New York),
- Creation of resource agency review process for the long-range transportation plan (South Carolina),
- Development and execution of an annual sound land use implementation plan (Pennsylvania), and
- Design of a watershed restoration plan in a partnership among the state transportation agency, state natural resource agency, and local governments (Maryland).

[2] Colorado, Delaware, Florida, Indiana, Louisiana, Maine, Maryland, Michigan, Montana, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, South Carolina, Tennessee, and Wisconsin.

**SUMMARY**

Among the commonalties between environmental stewardship and environmental streamlining are the need for more information on existing practices, the development of innovative tools for improving practices, improvements in data resources and data analysis techniques, and the establishment of metrics for measuring results. Because both topics involve shaping human behavior, there also is a demand for techniques for creating and managing cultural change in state and federal agencies involved in transportation. Effective research in each of these areas is critical to the future success of environmental streamlining and environmental stewardship in transportation.

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RESEARCH NEEDS STATEMENTS

# Environmental Streamlining and Stewardship

## 1. EFFECTIVE ORGANIZATION AND PRACTICES FOR ACHIEVING ENVIRONMENTAL STEWARDSHIP IN TRANSPORTATION AGENCIES

**Problem Statement**

Transportation agencies from all modes are increasingly recognizing that embracing environmental stewardship provides intrinsic value to their communities and enhances their standing with their stakeholders/customers. They also acknowledge that environmental stewardship is an integral part of streamlining. Some agencies are implementing environmental stewardship more comprehensively than others. More research is needed to determine the organizational and other factors that contribute to successful integration of stewardship within the agency culture, encompassing all of the agency's principal functions.

**Proposed Research**

The research will focus on reviewing transportation agencies for strategies and tools that assist the agencies in integrating environmental stewardship into their cultures and into their business practices. The areas of organizational culture and business practices that should be evaluated include but are not limited to

- High-level leadership that communicates the need for environmental stewardship;
- Strategic plans and mission statements that reflect a commitment to environmental stewardship;
- Adequacy of budgetary commitments to fulfill the plans and missions;
- Placement, authority, and empowerment of key staff within the organization to implement environmental stewardship;
- Outreach to determine the customer's needs and expectations for environmental stewardship;
- Human resource decisions (hiring, recruitment, professional development, accountability, awards, and recognition) consistent with the objectives of environmental stewardship;
- Environmental management systems that promote environmental consciousness in *all* agency functions;
- Performance measures for environmental stewardship;
- Continuous reevaluation and process improvement; and
- Partnering to achieve stewardship goals.

Proposed study tasks include:

- Conduct a literature review;
- Meet with transportation agencies from all modes, including state departments of transportation (DOTs) and major transit agencies;
- Synthesize data;
- Evaluate and summarize the most effective methods currently used; and

- Recommend ways in which environmental stewardship could be further enhanced (e.g., management and organizational techniques).

**Cost:** $400,000
**Duration:** 15 months

### 2. USE OF INFORMATION TECHNOLOGY FOR ENVIRONMENTAL STREAMLINING AND ENVIRONMENTAL STEWARDSHIP

**Problem Statement**
Gains in U.S. economic productivity in the last 20 years are largely attributable to advances in information technology. Nevertheless, the transportation/environmental sector is not taking full advantage of information technology. Many off-the-shelf information technology tools are not being fully utilized because of a lack of awareness and resistance to change. Specific information technology tools are not being developed because they compete ineffectively for governmental development funding and do not represent a large enough market to interest private development.

**Proposed Research**
This research would have two elements: (*a*) dissemination of existing information technology and (*b*) foundational work to develop customized information technology tools for specific environmental stewardship and streamlining applications.

***Information Technology Dissemination***
Update and supplement the existing NCHRP effort, "Technologies to Improve Consideration of Environmental Concerns in Transportation Decision-making," by surveying emerging information technology tools used in the environmental streamlining and environmental stewardship areas. Create a mechanism for continuous updating of product information and showcasing of relevant information technology tools, potentially through a partnership involving TRB, AASHTO, U.S. DOT, and other stakeholders. Perform analyses of selected tools to determine the benefits of using these tools in terms of cost or time savings or other productivity enhancement.

***Specific Product Development***
Conduct market research among practitioners to see which specific products are in greatest demand. Determine the level of effort required to develop specific customized products. Propose a product development process that would address information technology compatibility. Select one product for pilot development; such as "turbo-4(f)" software that would interview a practitioner, educate them about the topic, guide them through the regulatory process for 4(f), and prepare legally sufficient documentation. Other possible areas for development of a Turbo-Tax-style software include categorical exclusions, Section 106 coordination, and scoping. Explore institutional arrangements for developing and updating such information technology tools. This might include public–private partnerships where development costs are shared between government and private companies and marketing and updating become the responsibility of the private partners.

If the specific product development pilot is successful, subsequent work might include integrating it with other information technology systems or developing additional tools.

**Cost:** $600,000
**Duration:** 18–24 months

### 3. Identification, Development, and Evaluation of Performance Measures to Determine the Effectiveness of Environmental Stewardship and Environmental Streamlining Initiatives

**Problem Statement**
Transportation and environmental protection stakeholders agree that when transportation agencies embrace environmental stewardship, they can reduce environmental impacts, cost, and schedules for their projects. Measuring progress on implementing stewardship and streamlining initiatives is critical.

Some transportation agencies have begun to develop quantitative and/or qualitative performance measures to evaluate the effectiveness of their stewardship and streamlining programs. Nationwide, however, use of performance measures in this area is limited, as is the understanding of best practices, and there is a significant opportunity to develop new types of performance measures.

**Proposed Research**
Conduct a three-part research project to examine best practices, develop new performance measures, and create tools for practitioners applying performance measures. The research project will independently investigate performance measures for evaluating environmental stewardship and environmental streamlining since these issues are closely related, but separate. The tasks are to:

1. Review Best Practices for Performance Measurement (12 months)—Investigate how a selection of transportation agencies are incorporating environmental performance measures in their programs.
   - Identify, describe, and review measures and the management frameworks in which they are implemented.
   - Examine strengths and weaknesses of these approaches.
   - Review relevant practices by other industries and public agencies.
   - Outreach with key stakeholders to gather their perspectives on performance measures needs.

***Interim Deliverable***
Provide a best practices report that can be distributed as hard copy and electronically (web-compatible). Complete by month 12.

2. Develop Performance Measures Pilot Program (24 months, simultaneous to Part 1)—
From the information gathered from Part 1 above, develop new and innovative performance measures by working with a small number (four or five) of state transportation agencies (6 months). Track and evaluate the effectiveness of these performance measures (18 months).

***Interim Deliverables***
Electronic (web-based) report on methods used to develop performance measures (9 months), addressing issues such as data collection, measurability, presentation methods, etc.

3. Prepare Performance Measurement Design Tool for Practitioners (ongoing)—
Synthesize the results of Parts 1 and 2 of the project, including lessons learned from tracking and evaluation of performance measures in pilot states. Use this information to develop a tool that provides a framework for practitioners as they develop performance measures that address streamlining and stewardship goals.

***Final Deliverable***
Electronic (web-based) report on results of implementation of measures (24 months).

**Cost:** $400,000
**Duration:** 2 years

**4. Evaluation of Environmental Process Delays**

**Problem Statement**
Those within and outside the transportation organization have identified that the NEPA process takes an excessive amount of time, leading to project implementation delays. There is inadequate data to determine specific causes of project delays and to determine if nationwide trends exist.

**Proposed Research**
The proposed research would identify specific reasons for project delays and develop recommendations for streamlining the process. The researcher shall develop a methodology for data gathering and analysis to include the following:

- Review past studies by individual states, U.S. DOT, TRB, and others that identify delays in the project development process;
- Select a representative cross section of projects of varying degrees of complexity and impacts (minimum of 35 projects using random sampling) as case studies to determine the process used, project management systems used, and causes for project delays, as documented by project files in DOT and participating agencies. The causes for delay could include other than environmental reasons;
- Conduct a 360-degree survey (questionnaire and interviews for transportation agency staff, resource agencies, local governments, and others) to complement the database of project delays. The survey of transportation agencies should include the identification of formal and informal project management systems used; and
- Synthesize data to determine the most pronounced reasons for project delays.

A report will be provided in Word and web-based formats to document the findings of the research.

Careful consideration must be given to identification of appropriate staff at participating agencies to ensure that the information obtained correctly portrays the project process and associated delays. Confidentiality of project information provided will be assured.

**Cost:** $400,000
**Duration:** 18 months

### 5. The Use of Tier I Environmental Impact Statements in the Transportation Planning Process

**Problem Statement**
The National Environmental Policy Act (NEPA) permits Environmental Impact Statements (EISs) to be performed in tiers or stages. Tier I of an EIS would typically examine a range of alternatives at a transportation corridor or system level. The current emphasis on environmental stewardship and environmental streamlining is resulting in more frequent use of Tier I EISs early in the transportation project planning process. NEPA and its implementing regulations provide little guidance about when the preparation of a Tier I EIS is appropriate, the level of analyses needed, and the tools necessary to perform the analyses.

**Proposed Research**
The research will examine selected case studies to determine

- The circumstances under which Tier I EISs were prepared,
- The tools used to prepare Tier I EISs,
- Whether the use of a Tier I EIS facilitated the choice of multimodal alternatives,
- Whether or how Tier I EISs addressed the issue of secondary and cumulative impacts, and
- Whether Tier I EISs resulted in environmental streamlining and environmental stewardship.

Current constraints and issues regarding the use of Tier I EISs, as well as unexpected outcomes, will be reported. Among the topics to be examined is the use of a Memorandum of Agreement designed to:

- Promote an understanding of the decisions that a Tier I EIS could cover,
- Discuss the appropriate role of other agencies in a Tier I EIS process, and
- Describe a Tier I EIS's relationship to follow-on environmental documentation.

Products will include criteria for when the use of a Tier I EIS is appropriate, a framework template for the contents of a Tier I EIS, and guidance on how to perform meaningful impact analyses that meet legal and environmental regulatory requirements.

**Cost:** $250,000
**Duration:** 12–18 months

## 6. Putting It All Together: Restructuring the Federal Environmental Review System

### Problem Statement

The legislative objective of NEPA is to provide a framework for integrated and balanced decision making; however, the integration and rationalization of substantive laws and rules into a managed system has never occurred. The system is additive, without coordinated evaluation of the effects of new initiatives on the process. As a result, the environmental review process grows in complexity, which encourages resistance to compliance and frustrates the expectations of legislators and the public. Because the system is large, complex, and lacks comprehensive oversight, it is difficult to understand the interrelationships among the parts. It also may result in unintended adverse consequences to the environment. Development of comprehensive improvements is problematic, because there is no effective tool that defines the environmental review system as a whole and facilitates an examination of it.

### Proposed Research

The objective of the research is to identify potential improvements to the environmental review system that will make it easier to reach good decisions, so that more energy goes into meaningful evaluation and less into conflict. To simplify and integrate the system while improving environmental outcomes, two products are required. First, the creation of a synthesis that describes, in an easily understandable way, the structure and operation of the existing system. Second, the design of alternative models for the system and its management that will restructure and simplify the system, while enhancing environmental protection.

This research structure contemplates two phases and two stand-alone products. The results of Phase One will include a suggested scope of work for Phase Two. Both phases of the research should incorporate consultation with a sampling of federal, state, and local decision makers, as well as interest groups. Each research report should use simple graphics and other methods to make the results easy to comprehend so that they can be used as educational and management tools for a variety of audiences. The research will benefit agency executives, program managers, legislators, and the public.

*Phase One: Map of the Existing System*

This phase will result in two work products. The first product of the research will be a synthesis describing the current system and how it functions. The synthesis will enable people to develop a baseline understanding of the relationships between NEPA and the various laws that apply to transportation development, and also

1. Summarize succinctly the existing laws and regulations, including:
   - Intent and objectives,
   - Basic decision-making pathways,
   - Types of data required for a decision,
   - Decision makers, and
   - Whether the specific requirement results in an advisory opinion or a binding decision.
2. Analyze the interrelationship among the laws and regulations.
3. Describe the process by which new requirements are inserted into the system.

4. Identify existing processes and mechanisms for managing the scope and growth of the system [e.g., Council on Environmental Quality (CEQ), congressional committees].
5. Evaluate whether the existing system presents barriers to streamlining and environmental stewardship.
6. Provide examples that illustrate any duplication, choke points, or unmanaged growth in the system requirements.
7. Specify any problem areas.
8. Recommend system improvements to simplify and rationalize the system's operation and to enhance environmental outcomes.

The second Phase One product will be a scope of work; the budget and schedule for Phase Two. Phase Two will produce models for an improved system based on the research results. A suggested concept for Phase Two is outlined here.

*Suggested Phase Two Concept: Design of New System Models*
Based on the synthesis results, develop at least two models for a restructured environmental review process. Development of the models would be conducted under the auspices of an appropriate advisory committee or other entity such as CEQ. The objective is to produce models that offer a range of choices, including at a minimum

- A model that can be achieved through administrative and management changes only, requiring no major legislative/regulatory action; and
- A model that reflects a broad vision for a unified process that produces comprehensive and balanced decisions and specifies necessary legislative/regulatory changes.

Each model would demonstrate how it:

- Avoids duplication and reduces system choke points;
- Simplifies and increases the effectiveness of administration;
- Uses existing, but underutilized, administrative or other mechanisms where appropriate to achieve the goals;
- Considers the interfaces among federal, state, and local regulatory programs;
- Manages system changes and new initiatives to avoid duplication;
- Meets overall environmental protection objectives of existing laws and regulations; and
- Provides opportunities for enhanced environmental protection.

**Cost:**
- Phase One: $1.25 million
- Phase Two: To be determined

**Duration:**
- Phase One: 12 months
- Phase Two: To be determined

**Collaborative Research Needs Statements**

## 7. THE ROLE OF PUBLIC INVOLVEMENT IN ENVIRONMENTAL STREAMLINING

For full text, see Section 13 under Community Impacts, Environmental Justice, and Public Involvement

## 8. Community Impact Assessment, Public Involvement, and Title VI/Environmental Justice: Streamlining Multimodal Transportation Projects Through Practitioner Experience

For full text, see Section 14 under Community Impacts, Environmental Justice, and Public Involvement

## 9. Evaluate and Extend the Florida Efficient Transportation Decision-Making Process (Streamlining) for Use in Other States

For full text, see Section 7 under Environmental Information Management

# Integrated Environmental Decision Making

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Resource Paper

# Integrated Environmental Decision Making

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Beginning in the 1960s and 1970s, incorporating environmental considerations and impact analyses into transportation decision making became a necessity. To complete the mandated analyses, the ecosystem was broken into components and individual modal impacts were evaluated. Today, society is seeking more complex project results including aspects of sustainability and stewardship. The tools that were developed to support decision making under the current paradigm do not adequately address the current complexities. The purpose of this paper is to suggest that a "paradigm shift"' is necessary to ensure that the environment, together with other key transportation factors that influence the decision-making process, are more effectively integrated in a cost-effective and efficient manner. For transportation projects to be successful in the 21st century, environmental considerations must be part of a systemic decision framework that encourages sustainability and environmental stewardship. Furthermore, the framework must be inclusive of all interests, so that informed decisions can be made that fairly represent various stakeholders.

## INFORMATION

The environmental problems that were faced in the 1960s and into the 1970s were divided into categories (air, water, waste, oceans, etc.) to develop laws, regulations, and strategies designed to focus on each concern. This reductionism approach segmented the environment into treatable elements or media, primarily because people tend to specialize in one media or another; nevertheless, the ecosystem remained a system. As the world population and its by-products have increased, the divisions between media have shrunk and in many cases disappeared. Potential environmental impacts must now be addressed systemically across media.

Another sector that has moved from being considered a series of individual components to a system of interconnected elements is transportation, whether passenger or freight. A container of tennis shoes may move by water, then by rail, and ultimately by truck to reach the consumer. A traveler going to another city may use a train, airplane, taxi, and bus or some combination thereof to reach a destination. Recognizing that transportation is now used and perceived as a system rather than as discrete modes demands that transportation decision making be increasingly integrated across modes or multimodal, and it must be more expansive (global), considering routes that may span continents. To make informed transportation project decisions, environmental analyses must move towards being systematic with the integration of impacts across media and modes to determine the real consequences of projects.

The task of environmentally integrated decision making is a challenging one. The complexity, lack of appropriate information, and conflicting public policy goals often exacerbate the difficulty in making effective decisions. Whereas a large body of literature exists on complex system design and systems analysis, there is clearly a definite research need to successfully make a paradigm shift from a components assessment to more effectively integrate environmental and transportation decision making.

The current paradigm typically consists of separate planning, project design, and maintenance/operations decision making, with environmental considerations restricted to compliance with environmental regulations. Adversarial relations among the stakeholders, rather than cooperative relations, have generally characterized the process. Few, if any, incentives exist for cooperation and many barriers exist to developing cooperative approaches to incorporating environmental considerations in transportation decision making. Issues such as sustainability, stewardship, and streamlining are new values being discussed by our society as desirable aspects and outcomes of the project process, but they cannot be attained when there is a lack of a cooperative, comprehensive decision-making framework.

This old paradigm results in a transportation infrastructure that is not meeting needed capacity or contributing to environmental objectives. This failure, in turn, affects the viability of community, environmental health, and transportation systems at the local, state, and national level.

## PARADIGM SHIFT

To make this paradigm shift to a systematic framework that has integrative features (i.e., sustainability and stewardship) and is streamlined, research is required in several areas. This research includes investigations of both conceptual and strategic changes. Elements of these two shifts are outlined below and reflected in the Research Needs Statements.

### Conceptual Shift

- Compliance to Performance—Moving from an environmental compliance framework to an environmental performance-based framework will enhance project outcomes. Compliance often results in the lowest common denominator solution, on a project-by-project basis, and a performance-based solution yields outcomes that achieve systemwide goals.
- Incentive-Based Framework—The stick, rather than the carrot, is most often employed in environmental/transportation planning. On the other hand, incentive-based programs are often used in environmental stewardship programs in other disciplines. For example, the Farm Bill has a long history of this conceptual framework.
- Cooperation Rather than Competition—There is a need to integrate competing interests (public, private, and community) into integrated transportation and environmental decision making. Legal, regulatory, and systemic policies that are barriers to this approach need to be identified and corrected. Lastly, the disconnection between local and national transportation desires must be addressed and strategies developed that acknowledge that one size does not fit all.

### Strategic Shifts

- Provide Useful Tools to Decision Makers—Many environmental and transportation policy decisions are made based on model outputs and strategies encompassed in the current state of the practice. These strategies/models lack comparison factors. The state of the practice does not provide the level of information necessary to make informed decisions. However, new tools have not yet been developed that allow comparisons across modes and environmental media. Research is needed on innovative tools and strategies. Often these methodologies have been implemented and deployed in other disciplines. As an example, the application of scenario-based planning could provide a new way to view transportation/environmental planning. A common set of assumptions and metrics that allow comprehensive and useful comparisons across transportation modes and environmental media are needed for informed decision making.

- Development of Environmental Performance Measures—Transportation investments can be used more effectively in achieving transportation and environmental goals through a performance-based mitigation strategy than by means of the current compliance strategy. This approach allows environmental objectives to be set, balanced throughout the planning process, and evaluated (measured) following project implementation.

## CONCLUSION

The current decision-making paradigm used in the development and implementation of transportation projects has grown out of the regulatory and analytical processes from the 1960s and 1970s. The approach segments the environment and the transportation systems. Attempting to enhance the current decision-making paradigm does not go far enough in reaching the new systemic goals of sustainability, stewardship, and streamlining. To be successful in this 21st century endeavor research is needed on how to broadly integrate decision-making processes across media and modes. A new decision-making framework is necessary to address the environmental complexities and trade-offs characterized by the current and future transportation requirements.

RESEARCH NEEDS STATEMENTS

# Integrated Environmental Decision Making

## GOAL A: IMPROVING DECISION-MAKING PROCESSES

### 1. TRANSPORTATION AND ENVIRONMENTAL BENEFITS OR "HERDING CATS"

**Problem Statement**
Local governments, including municipalities, townships, and counties, together with school districts, park districts, and other local taxing bodies, must make many decisions to properly execute their duties. The same of is true of state and federal governments and their agencies. In doing this, there is often no consideration of the impacts or effects their decisions may have on other units of government. It can be as simple as constructing an arterial street that does not connect to an arterial street in an adjoining community. Another example may be the construction of sewer connections and treatment capacity that encourages new development without also providing adequate transportation facilities to serve the area. What can be done to encourage cooperation between different units of government and consideration of the effects of their decisions on others to produce integrated, synergistic government plans and programs to better serve the public?

**Proposed Research**
Research needs to be initiated to find locations across the country, and perhaps internationally, that have cooperated in planning and integrated decision making. The research should determine what circumstances or incentives were in place that resulted in such cooperation. The locations could be found through a literature search and through interviews with individuals who may have knowledge of government practices over a wide area. The existing circumstances can then be discovered through interviews with agency directors and managers to determine why they follow cooperative practices. The interviews should inquire not only about existing circumstances and incentives, but also about how they came into existence and led to current practices. The circumstances and incentives discovered should be carefully and fully documented. Once the examples are located and interviews conducted, the information recorded should be analyzed to determine if there are common components or factors that lead to cooperation and integration. In addition, it should be determined whether there are common circumstances or events that led to the existence of cooperative, integrated practices.

Beyond the basic question of whether cooperation and integration occurs and why, there is also a question regarding whether there were other benefits, such as dollar savings, economies of scale, reduction of conflict, or citizen approval/cooperation that were generally present, which might lead other government officials to see the benefits and also serve as a catalyst for cooperation and integration in other locations. The results should be incorporated into a report to be distributed to the usual TRB recipients together with umbrella groups representing various units of governments, including the National Governors Association and the National Association of Mayors.

Research activities would follow a stepwise developmental process including

- Task 1—Identify up to 10 locations that practice cooperative, integrated decision making.
- Task 2—Interview governmental and agency managers to determine why they practice such cooperation and what initiated that practice.
- Task 3—Analyze the information gathered to see if there are commonalities that would indicate what could be done to encourage such behavior elsewhere.
- Task 4—Distribute findings to governmental groups including the National Governors Association to disseminate such practices to operating governments and agencies.

**Cost:** $250,000
**Duration:** 24 months

### 2. BRINGING DIVERSE INTERESTS TOGETHER TO REACH ENVIRONMENTALLY SOUND TRANSPORTATION DECISIONS: INTERNAL AND EXTERNAL PLAYERS

**Problem Statement**
Relationships among the various agencies interested in developing environmentally sound transportation decisions have existed and been developed since the implementation of the National Environmental Policy Act. These relationships have changed (changing interests and resource issues, new players, etc.) over the years and can be characterized as cross-cultural. Each interest represents a set of values, missions, and goals that are not the same but which have points of integration with respect to transportation decisions. The cultural diversity includes but may not be limited to industry, carriers, retailers, public agencies, local, regional, and national governments, the public (communities, etc.), and special interest groups.

**Proposed Research**
We need to find more effective ways to bring diverse interests together to develop environmentally sound transportation decision making; therefore, the following tasks need to be accomplished:

- Identify the variety of approaches to conflict resolution and coordination that currently are used to develop environmentally sensitive transportation projects.
- Determine how effective these tools have been.
- Ascertain whether better tools can be provided.
- If yes, identify what needs to be done and how to go about it.
- Develop the tools to do this and the necessary materials to help users implement the tools.

**Cost:** $350,000
**Duration:** 30 months

### 3. DETERMINING BEST PRACTICES FOR INTEGRATING MULTIPLE AGENCIES AND NONTRADITIONAL STAKEHOLDERS IN ENVIRONMENTAL DECISION MAKING

**Problem Statement**
Highway 1 along the Big Sur coast traverses a landscape that is geologically young and actively eroding: landslides, rockfalls, and debris flows are commonplace. These processes create the visual drama and essence of the Big Sur coast. Highway 1 is a major travelling destination of

international acclaim. Although the local economy is dependent on tourism, the economic benefits of this resource have regional and statewide importance. On a national level, the route is recognized as an All-American Road under the Federal Scenic Byways Program.

A highly intensive effort is required by the California Department of Transportation on a year-round basis to provide safe and reliable travel on a highway that is subject to progressive natural alterations and episodic storm damage events. On a 75-mile stretch along the steepest areas, the lack of suitable detours can isolate communities and businesses and severely disrupt the local economy. The sensitive coastal environment and complex regulatory framework reveal what can appear to be competing interests. Decisions on highway repair involve multiple factors, but are largely driven by the regulatory agencies. As approvals for certain activities are negotiated and implemented on a case-by-case basis, the results can include project delays, high construction costs, and frustration. When the highway is closed in one or both directions, decisions are often made under pressure and are based on narrowly focussed criteria. Often, the path of least resistance is followed, which can result in collateral impacts that may be greater than those from a different course of action, but that require multiple party agreements. For example, the current practice for disposing of excess landslide material is long-distance hauling by truck to landfills. Some impacts are easily estimated, whereas others remain unknown. The subject of current debate is the degree to which material should be prevented from or allowed to contribute sediment supply to the ocean. Where one regulatory decision is avoided, other stakeholder interests can appear to be lost, resulting in added frustration.

Although there is an unending desire for scientific information to further understand the influence of human activities on the natural environment, there is a greater need to develop a structure for making sound decisions with the best available information. Aspects of environmental streamlining are needed to make the best all-around decisions.

**Proposed Research**

Evaluate practices (national and international scope) for integrating environmental decisions with multiple agency jurisdictions together with interested nontraditional stakeholders. Tailor best practices to the specific management needs for Highway 1 along the Big Sur coast. Determine best practices for making well-informed decisions that include

- Developing protocol for reaching multiparty agreements (in advance) for a variety of potential conditions and circumstances,
- Determining sufficient information needs to support decisions,
- Developing criteria for sound decisions,
- Integrating regulatory and nonregulatory considerations,
- Streamlining environmental decisions for best outcomes,
- Weighing decisions on environmental impacts outside of traditional environmental review procedures (i.e., emergency conditions), and
- Incorporating nontraditional stakeholder involvement in decision making.

This pilot study will evaluate and document practices that may be used when in the country.

**Cost:** $750,000
**Duration:** 30 months

### 4. Bringing Diverse Interests Together to Get to Environmentally Sound Transportation Decisions: Sponsor and Review Agency Perspective

**Problem Statement**

An increasing demand for effective transportation improvements for goods movement has created new partnerships and relationships that influence decisions on what transportation improvements will be made, what they will look like, and where they will be implemented. Some of these relationships have existed longer on the passenger side of transportation but have become increasingly complex. These relationships can be characterized as cross-cultural. Each interest represents a set of values, missions, and goals that are not the same but which have points of integration with respect to transportation decisions. The cultural diversity includes but may not be limited to industry, carriers, and public agency sponsors and reviewers. The focus of this research is identifying private sector and agency cooperation to define, develop, and implement projects.

**Proposed Research**

The definition of an intermodal freight transportation project can reflect the different jurisdictions of federal agencies and private sector needs. The variation in public agency approaches to integrating environmental issues into the location and design of projects can result in a somewhat fragmented process leading to decision making, plus a complex approach to involving environmental review agencies. The private sector operates on a very short time frame compared with government and is focused on its ability to succeed or fail, with success tied to being competitive, profits, and market position. Environmental resource agencies may not be overly concerned with the factors that drive private industry. The challenge is how to bring these interests together to make sound environmentally sensitive transportation decisions in a time efficient manner. Also, how can we bring the private and public sector interests together to consider environmental factors before designing and location decisions are made? Research tasks include completing the following:

- Identify how to define projects to reflect the actual intermodal activity (e.g., water improvements at ports, landside port improvements, and landside access) rather than breaking projects into parts that affect schedules and the amount of coordination and documents. This will require identification and description of representative case studies.
- Identify barriers that exist to developing cooperating agency agreements (to develop Memorandums of Understanding, Memorandums of Agreement, and one environmental document rather then two or more). How can they be overcome?
- Identify previous activities (good and bad) and evaluate.
- Develop approaches (see other bullets) to reach better integrated environmental and transportation decision making.
- Develop marketing approach and educational materials

**Cost:** $350,000
**Duration:** 30 months

## GOAL B: INTEGRATING TRANSPORTATION INTO COMMUNITY, ENVIRONMENT, AND ECONOMIC DECISION MAKING

## 5. Scenario-Based Planning to Balance Long-Term Transportation, Community, Environmental, and Economic Goals

### Problem Statement

There is growing frustration with the results of current state, regional, and local transportation and community decision-making processes. Transportation needs are not integrated or addressed in land use, economic, and other community planning efforts. Expensive and time consuming transportation planning processes and environmental reviews often do not result in projects being built or improvements in the quality of life, environment, or economic opportunities in communities. Current planning processes include 3-, 5-, and 20-year horizons, with major transportation infrastructure projects taking from 10 to 15 years to complete. Participants in the process often become polarized and unable to develop consensus because the range of solutions is limited to the scope of existing programs, agency missions, and resources. Solutions and alternatives are often developed in "stovepipes" and do not take into account the impacts of decisions on other goals. Although research is being conducted to improve existing processes, research is also needed to develop and test alternative processes to give decision makers additional tools to effectively address long-term transportation, community, environmental, and economic goals.

### Proposed Research

Scenario-based planning starts with the creation of a future "end state," where decision makers work together to create action plans to best reach that end result. By starting with an outcome and set of circumstances that may be 40 or 50 years or even 7 generations into the future, decision makers are taken out of their current "turf" and can think more creatively and collaboratively. The research specifically would explore

- How scenario-based planning can be used to meet and balance long-range transportation, environment, community, and economic goals;
- How scenario-based planning can be used to weigh and balance economic growth and development with other environmental factors;
- How scenario-based planning can integrate competing public, private, and community interests and results in transportation solutions;
- How scenario-based planning can integrate multiple levels of decision making from community, local, regional, statewide, and national, to global;
- How scenario-based planning can be used to develop alternative compliance with environmental goals into public and private initiatives; and
- How the results of scenario-based planning link with and support current environmental and planning requirements.

Research tasks would include:

1. Surveying current scenario-based planning applications and collect successful strategies and practices that would be applicable and effective in transportation decision making.
2. Developing, testing, and evaluating scenario-based planning for local, regional, statewide, and national transportation and environmental applications.

3. On the same issue, comparing the outcomes of a current transportation and environmental decision-making process with a scenario planning process.
4. Develop guidance, training, and materials to share effective strategies with decision makers.

**Cost:** $1,000,000
**Duration:** 36 months

### 6. MEASURE CHANNEL AND WATERWAY CAPACITY TO MAXIMIZE CURRENT INFRASTRUCTURE WITHOUT HARM TO THE ENVIRONMENT

**Problem Statement**
The waterways are essential elements of both our national and global marine transportation system. More than 95% of our overseas trade by volume is transported by ship. Most forecasters predict that waterborne trade will more than double over the next 20 years, and that usage of our waterways as an option to landside congestion will be expanded over the same time frame. In addition to commercial users, the number of recreational users is also expected to increase. Although meeting the users needs is important for our economy as well as our quality of life, we cannot forget that the waterways are also a valuable source of renewable and nonrenewable environmental resources. In light of the projected increases in use, there is increasing concern that additional vessel traffic will result in, or, in some places exacerbate already existing, waterway congestion. This will require identifying the need for future investments in waterway infrastructure before infrastructure shortfalls unduly impact waterway users or harm the environment.

**Proposed Research**
Waterway capacity may be an important management tool for waterways managers, but there is neither a clear nor universal understanding of what waterway capacity is. It can be understood as an indicator of a waterway's ability to physically accommodate a particular size of ship or the number of ships that can transit a particular water area at the same time. Define "waterways capacity" and develop a model(s) to simulate traffic flow in and out of port areas. The model needs the flexibility to change waterway features such as dimensional components (channel size—depth and width), vertical clearance, and unique waterway features that restrict waterway area such as anchorages, or environmentally sensitive areas, so that it can be used in any port. Initially the model would be used to simulate existing traffic, including all mixed uses of the waterway and to determine the water space required for the operation of and space between the different types of vessels. Research should include how the model could be used to identify the impacts increased traffic will have on environmental resources (i.e., increase proximity of vessels to resources), as well as increasing demand on channels and port facilities. Furthermore, this information can be used to make reinvestment decisions for infrastructure as well as to identify environmental effects of increased capacity. Current traffic levels would establish a baseline and projected increases in traffic could be simulated to determine infrastructure and environmental needs.

**Cost:**
- Task 1: Survey the available literature on capacity that could be applicable to the marine transportation system—$100,000.

- Task 2: Develop the scope of the project, including methodologies based on the results of Task 1—$75,000.
- Task 3: Construct a model that considers factors such as dimensional analysis, geometry, capacity, and alternative analysis—$300,000.
- Task 4: Apply the model and evaluate the effectiveness including calibration and validation across several environmental scenarios and facility (port) considerations—$300,000.
- Total costs: $775,000.

**Duration:**

- Task 1: 9 months
- Task 2: 6 months
- Task 3: 24 months
- Task 4: 18 months

This first phase would develop baseline definitions for modeling capacity across multimodes and simulate existing/future traffic to identify environmental factors that need to be addressed when developing plans to accommodate projected future growth.

## GOAL C: MOVING FROM ENVIRONMENTAL COMPLIANCE TO ENVIRONMENTAL PERFORMANCE

### 7. DEVELOPING BEST PRACTICES AND ANALYTICAL TOOLS FOR INTEGRATING TRANSPORTATION AND ENVIRONMENTAL CONSIDERATIONS IN TWO PHASES

**Phase I** involves development of integrated analytical tools and practices to enhance travel-demand forecasting across modes, including freight movement.

**Problem Statement**

In the current state of practice there are no tools and best practices available that allow for fine-scale integration of macro-, meso-, and microscopic (regional, corridor, and local scale) modeling. This precludes decision makers from having an integrated framework for informed decision making as it relates to environmental considerations. For example, a decision maker may be confronted with alternatives that cross modes with little to no way of confidently predicting mode shifts or micro-level impacts. The result of this lack of information can lead to decisions which over- or underestimate the relative impacts on the environment and the transportation system.

**Proposed Research**

To fill this gap it is necessary to

1. Evaluate the current macro-, meso-, and microscale modeling; this includes the validation of travel behavior assumptions used in these techniques;
2. Identify research techniques that allow for better forecasting of all aspects of travel, including mode shifts, activity analysis, and multimodal analysis including freight and related environmental impacts;

3. Establish and define best practices and guidelines for modeling, which allow decision makers to have levels of confidence in the results portrayed.

**Cost:** $400,000

- Task 1: Survey (literature, interviews, comparisons of models/modality practices)—$100,000.
- Task 2: Identify research techniques—$200,000.
- Task 3: Prepare best practices manual/guidelines—$100,000.

**Duration:** 31 months

- Task 1: 9 months
- Task 2: 12 months
- Task 3: 10 months

**Phase II** calls for integration of best practices and analytical tools across modes and media for assessing factors that have environmental considerations.

**Problem Statement**

In the current state of practice there are no tools and best practices available that allow for comparisons of environmental impacts and performance across modes. This precludes decision makers from having an integrated framework for informed decision making. Likewise, across environmental media/considerations, there is a lack of common assumptions and metrics, which preclude useful comparisons. For example, a range of alternatives may effect air quality, water quality, and environmental justice considerations. However, there is no way to compare and analyze across modes and across media.

**Proposed Research**

To fill this gap it is necessary to

1. First survey the state of practice,
2. Identify research techniques that allow for compatibility among modeling interpretation and evaluation, and
3. Establish and define best practices and guidelines for modeling that allow decision makers to have levels of confidence in the results portrayed.

**Cost:** $500,000

- Task 1: Survey (literature, interviews, comparisons of models/modality practices)—$100,000.
- Task 2: Identify research techniques—$200,000.
- Task 3: Prepare best practices manual/guidelines—$200,000.

**Duration:** 36 months

- Task 1: 12 months
- Task 2: 14 months
- Task 3: 10 months

## 8. Development of Environmental Performance-Based Mitigation Systems

**Problem Statement**

The current practice for mitigating environmental impacts of transportation projects is to mitigate only specific impacts on specific resources without consideration of which produces the best environmental result. In many cases, significant funds will be spent by transportation agencies on marginal mitigation projects. Those same funds could be spent to much greater environmental benefit consistent with larger environmental and community goals. By changing to an environmental performance-based mitigation methodology, transportation investments can be used more effectively in achieving both transportation and environmental goals than under current regulatory structures. To achieve this change in paradigm, acceptable methods for setting regional environmental objectives, measuring environmental impacts, and measuring environmental performance by its contribution towards the identified regional environmental objectives must be developed.

**Proposed Research**

The proposed research is intended to explore methods of optimizing transportation-related environmental investments instead of the current piecemeal responses to mitigating specific project-related impacts. Toward this end, the following tasks should be initiated:

- Task 1: Determine the state of practice of environmental performance-based mitigation.
- Task 2: Decide what regulatory, legal, and policy barriers exist to performance-based environmental measurement and mitigation.
- Task 3: Establish what alternative regulatory structures can accommodate performance-based environmental mitigation.
- Task 4: Develop common environmental performance measures across modes that can be accepted by resource agencies and other stakeholders.

**Cost:** $500,000

- Task 1: $100,000
- Task 2: $100,000
- Task 3: $100,000
- Task 4: $200,000

**Duration: 24 months**

- Task 1: 6 months (parallel)
- Task 2: 6 months (parallel)
- Task 3: 9 months (parallel)
- Task 4: 12 months

## 9. Finding the Carrot Instead of the Stick

**Problem Statement**

Planning, construction, and operations of transportation projects frequently ignore environmental goals, including community desires and needs, until there is an adverse reaction. Someone brings out the "stick," and the project is reformulated or retrofitted to address the deficiency at a significant cost and/or time delay.

The traditional transportation planning and environmental analysis processes or project operations generally leave the identification and mitigation of environmental needs, including habitat protection, historic preservation, and community desires, until the end of the project formulation stage or when there is a problem. At this point, formal comments or pressure from regulatory and resource agencies; from the community, including environmental stakeholders; or from political officials result in changes in the project (e.g., expensive reformulations to protect natural or human resources) because of threats to the project's acceptance and viability. If there were a scoping framework to redefining the purpose transportation project at the outset and identifying comprehensively all relevant needs/purposes/benefits, then the project could be supported and empowered by multiple constituencies. The incentive for the owner using the framework would be to limit surprises and to control cost and duration. Other incentives could be offered the owner such as tax reductions or write-offs, right-a-way easements, etc. The downside to providing environmental/community benefits for transportation projects is that they become visibly more expensive at the outset (instead having a cost overrun at the their completion) or their operating expense increased. Other forms of incentives may affect local tax revenue or future land-use decisions.

**Proposed Research**

There are many more questions than answers in this area. How can an incentive-based framework be used to achieve environmental goals during the development of transportation projects including infrastructure construction and project operations and maintenance? How can existing national, state, and local bureaucratic processes be used to promote a new incentive-based framework while de-emphasizing current adversarial tensions? Are there models from other sectors that use incentive-based methods to influence behavior and decision making? Are there sufficient demonstrated benefits for applying an incentives-based framework in transportation project formulation, development, or operations to risk not have the project funded? Does this approach enable environmental goals to be identified simultaneously with the transportation goals? How should a framework be structured that enables a project management to know that all potential project purposes have been identified? If at the beginning of a project (during a Tier I environmental impact statement stage) a project manager used a public scoping meeting to identify economic development, community improvements, or habitat restoration, would a greater number of other agencies become cooperating agencies in the process? Are there mechanisms for funding transportation projects that have crosscutting benefits at the federal, state, and local level?

**Cost:** $250,000
**Duration:** 24 months

# Land Use and Transportation

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RESOURCE PAPER

# Land Use and Transportation*

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The 1990s witnessed increased awareness of the role of urban form in shaping household activity patterns and travel choices. By the close of the millennium, important strides had been made to encourage better coordination between land use and transportation. Requirements specified within the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and subsequent language in the 1998 Transportation Equity Act for the 21st Century (TEA-21) called for an increased role on the part of metropolitan planning organizations in coordinating regional transportation investments with local land use actions. The Clean Air Act Amendments of 1990 (CAAA) also highlighted the environmental implications of land use and transportation decisions. With the passage of ISTEA a year later, a fiscal nexus was established between transportation funding and air quality. For the first time ever, regions had to demonstrate the ability to conform with the CAAA's National Ambient Air Quality Standards within a set time frame or were threatened with the loss, or more likely diminished control, of their federal transportation funding.

Toward the close of the decade, it became apparent that regions with the highest per capita vehicle miles of travel (VMT); for example, Atlanta, Georgia, and Houston and Dallas, Texas, were among those that had difficulty conforming to federal air quality requirements. What these regions have shared in common is a cadre of development and transportation investment practices that have facilitated their recent growth. Low-density single-use development (Cervero 1991; Handy 1996) mandated by exclusionary zoning (Knaap 1991), enabled by an increasingly ubiquitous system of auto access, and supplemented by disconnected street networks (Kulash 1990; Frank et al. 2000) corroborate to require increased vehicular travel for both work and to nonwork purposes. However, these Sunbelt regions are not alone. Several other high growth regions also experienced a considerable increase in hours of congestion during the 1990s (Lomax and Schrank 2001), along with low market shares for transit (Dunphy and Fischer 1996; Ross and Dunning 1997; Hu and Young 1999), and increasingly unsafe pedestrian environments (*Our Nation's Travel* 1997; *Mean Streets* 2000).

When projected into the future, these trends illuminate a growing schism between federal policy and local government action over the coordination of land use and transportation. Meanwhile, new implications for community design are beginning to surface. The release of the Surgeon General's Report, *Physical Inactivity and Public Health* (U.S. Department of Health and Human Services 1996) and subsequent research in *The Journal of the American Medical Association* (Mokdad et al. 1999) documents the emergence of an obesity pandemic. Although the eating habits of our *Fast Food Nation*[1] (Schlosser 2001) certainly are part of the equation, several researchers within the public health field have concluded that a pedestrian-hostile environment is also responsible for our increasingly fainéant lifestyle (Sallis et al. 1998; Frumkin 2002).

This polemic revolves around the link between observed reductions in the levels of physical activity contemporaneous with environmental conditions that discourage such activity

(Frank and Engelke 2000). These researchers have speculated that the most common form of physical activity in the built environment, walking, is unpleasant and even unsafe in many contemporary urban settings. These public health considerations suggest that planners, architects, and engineers need to develop a better understanding of how environments impact household activity patterns. The Robert Wood Johnson Foundation recently unveiled an ambitious set of research funding and outreach programs to promote physical activity or active living. The Robert Wood Johnson Foundation effort suggests that current approaches to land development and transportation investments may be out of alignment with public health and quality of life considerations. As research needs for the new millennium are defined, it is crucial that we give careful consideration to those strategies that are at the nexus of mobility and public health concerns.

### HOUSEHOLD ACTIVITY PATTERNS

Over the past decade our understanding of travel has evolved into a more holistic view of transportation patterns as a function of overall household activities. Increased understanding of the household's activities and of the spatial relationship of opportunities within the built environment (land use) has resulted in the increased awareness of how urban form shapes travel and time use (Bowman and Ben-Akiva 2001). Known as "activity" or "place based," surveys are also becoming more robust in the types of data that are being collected. In some cases, attitudinal data on the likely participation in various travel demand management (TDM) programs are being collected. Other data collection programs are including surveys on residential location choice and enabling linkages to be made between these stated residential preferences and revealed travel and urban form choices (Duann and Shiaw 2001).

According to Dutch researcher Guert Hupkes, total personal travel time per day remains relatively constant regardless of modes of travel selected (Hupkes 1982). Furthermore, Hupkes asserts that trade-offs are made between modes of travel to maintain what he describes as a daily travel time budget. The proposition that travel time budgets do exist and have remained stable is reinforced in a recent study of the twin cities Minneapolis and St. Paul, Minnesota (Barnes and Davis 2001). Such a notion is fundamental to explaining the likelihood to walk within the context of other time expenditures for work and nonwork travel. The earlier work of Hupkes, Zahavi, McFadden, and others suggest the need to understand household travel choice as a more holistic phenomenon and thus requires addressing other constraints that affect the travel decision-making process (McFadden and Reid 1975; Zahavi and Talvitie 1980).

### IMPROVEMENTS TO RESEARCH DESIGN

A research priority for transportation planners remains the development of a better understanding of land use and transportation relationships at a variety of scales, ranging from regional to site-level impacts. At the regional level, the tools that are available to model the relative travel and air quality implications of alternative transportation investment programs and growth scenarios remain crude. These tools are often criticized for their insensitivity to the growth-related impacts of major transportation investments. Most metropolitan planning organizations use modeling tools that do not adequately capture the induced demand of secondary growth impacts of major transportation investments that convert undeveloped areas to urban use.[2] Conversely, most regional models are unable to account for the effects of a variety of land use policies on travel choice and vehicle emissions. At the microscale, tools are needed to test the relative travel, air quality, and physical activity implications of alternative approaches to land development. These applications range from corridor or subarea scales to site-specific design considerations. At present, only a few regional travel models include nonmotorized modes as discrete travel options.

Data collection, data sharing, and ideological exchanges are now underway between the planning, engineering, architecture, and the public health sectors (*Healthy Places* 2000). There is a significant opportunity to leverage the data collection investments made across these sectors. For example, the simple addition of height and weight questions on a travel survey result in a useful database for the testing of urban form and activity pattern relationships with predictors of public health (SMARTRAQ 2000). Conversely, adding locators such as nearest intersection to the trip ends of respondents within health-related surveys creates the opportunity to test relationships between health outcomes and urban form. An exchange of information at the technical and policy levels promises to improve transportation and land use planning in ways that embrace the concerns of other affected sectors of the economy. This collaboration holds considerable hope for the advancement of the results of our research and the application of the tools we create. Along with the heightened awareness of the need for better coordination between land use and transportation is the need for not only more robust data, but also improvement in conveying information to decision makers. Investigating land use and transportation relationships has long been hampered by limitations associated with available data. However, vast improvements in land use and transportation-related data collection processes, supported by means of technical advancements over the past decade, now enable research to be conducted at scales and degrees of freedom that were previously unavailable. Although several improvements have been made, the application of such advancements within geographic information systems (GIS) environments remains limited to a few projects.

**Multiple Scales of Analysis**

Federal policies call for increased sensitivity to land use throughout the travel demand modeling process. Work needs to be done to enable lessons learned from activity- and place-based modeling efforts such as TRansportation ANalysis SIMulation System (TRANSIMS), along with other recent off-model developments, including the Smart Growth Index and Places Three Models, to be brought into common practice. Interactive modeling frameworks that operate at a variety of geographic scales are required. Specifically, land use and transportation investment actions require microscale simulation tools to test the effects of site design and other localized effects on travel. However, the ability to assess the regional impacts of such proposals requires the ability to place the study area, and the localized impacts, within the context of the regional modeling framework.

**The Where (Regional Location) and the How (Local Area Design)**

The regional context (where), local context, and project attributes (how), either corridor level or site level, constitute three scales of analysis that should be taken into account in assessing the impacts of a land development or transportation investment decision. Both the *how* and the *where* questions are fundamental to our ability to gauge the impact of land use patterns and transportation investments:

- The how question for land use means site design, whereas for transportation investment it means funding per mode and intermodal connectivity impacting the relative ease of travel across modes; and

- The where question implies regional location; for example, central city, suburbia, exurbia, or infill and brownfield versus greenfield and local community context, as defined by physical, sociopolitical, and attitudinal attributes.

The risk of not addressing these two sets of factors, one operating at the regional and the other at the local scale, is a lack of critical consideration of the likely outcomes of a particular development action. For example, taken out of context, some development projects claiming "new urbanist" principles could be viewed as generating considerable air quality and transportation benefits for the community. However, when placed within a regional framework, projects in greenfield locations at the urban fringe may offer relatively few employment opportunities nearby and limited transit service. As a result, they may not meet regional travel and air quality objectives. On the other hand, depending on mix of uses and scale of development, they may offer opportunities for increased walking and for meeting nonwork travel needs through nonmotorized transportation as compared with low-density, single-use development. The inverse logic holds true for auto-oriented developments: those that are placed in infill locations do little to woo travelers from their cars, despite their proximity to a wider range of possible destinations. The infill locations may lead to shorter driving distances and less vehicle emissions than auto-oriented developments on the fringe. However, the concentration of vehicle emissions in these infill locations remains a concern.

A multiscale framework that addresses the regional, local area, and site-specific attributes of a particular land development and/or transportation investment action would advance the rigor of future studies designed to assess travel and air quality outcomes. Recent advances in the ability to spatially register various types of data (e.g., transit coverage, parcel-level land use, roadway level of service, aerial photography, crime, and pedestrian incidences) supports multiple geographic scales of analysis. Such an approach to analysis would enable evaluations that are more consistent with the tenets of smart growth, which seeks to promote the most efficient usage of existing infrastructure and of our natural resources. Given that a considerable number of neotraditional developments are now occupied, including the Kentlands (Maryland) and Meisner Park (Florida), it is timely to conduct a systematic assessment of the actual travel and activity patterns of residents, employees, and commercial patrons of these developments.

**Case Study Approach**

The Environmental Protection Agency recently conducted a study to compare the VMT and vehicle emissions that would likely result from a similar development located in four different places in the Atlanta region─one of the locations being the proposed brownfield location of the 8 million-square-foot Atlantic Steel Development. The results of this study are shown in Figure 1. The study concluded that, all else being equal, the lowest level of VMT and emissions were associated with the most central development location (no. 1 on map). These findings led to the first transportation control measure (TCM) that includes a specific land use action within its definition.[3]

However, a central location is not enough to demonstrate reduced emissions, more transit and walking, and lower vehicle usage. As part of this TCM, the Atlantic Steel Project needed to comply with a host of "how" or site-design criteria. This was in recognition that regional location or the "where" side of the equation alone would not reduce auto dependence. This example offers additional illustrative value through its integration of locational (where) and urban design (how) criteria and sets a precedent for the creation of TCMs that tie transportation investment with land use.

## EMERGING RESEARCH NEEDS

A great deal has been learned in recent years about the ways in which land use and transportation interact (Cervero and Ewing 2001). However, significant gaps remain in our ability to explain or to predict the outcome of specific land use policies and transportation-investment actions. Presented here are some of the emerging areas where considerable effort is required to help provide practitioners with analytical tools and approaches to addressing the types of questions that are now surfacing. Some of these areas of inquiry have always been of great interest to planners, decision makers, and even the general public, but were not accessible. In some cases they are now becoming available through vast improvements in data and computing methods. As outlined below, improvements in GIS software has enabled the matching of travel patterns with "household specific" land use information.

### Activity Center Design: Trip "Generators"

A considerable amount of research has assessed how the design of residential areas impacts travel and activity patterns. However, relatively little work has been done to better understand how employment and other activity centers impact these same behaviors. Research is needed to understand how land use attributes at both residential and employment or commercial and entertainment trip ends, when taken collectively, affect travel choice. There is a great deal that can be learned about the household travel choice implications of site design, parking supply and layout, and ease of access to retail uses in and around employment and other entertainment complexes. For example, estimating the potential benefits of various TDM strategies requires considering the presence of services within convenient access to employment locations. As demonstrated in previous research, the likelihood of participation within a TDM program (leaving the car at home) is also sensitive to land use patterns at the place of employment (Cambridge Systematics and Deakin Harvey Skabardonis 1994). However, research on the amounts and arrangements of particular land uses has never been conducted in this context. Given advancements in travel data collection, transit coverage and service data, and in the usage of parcel level land use information, such analyses are now possible. The recent emergence of entertainment complexes and the current retrofitting of existing activity centers in suburban locations makes this area of inquiry timely. Many regions are now looking at ways to stimulate redevelopment of gray field locations where current land use patterns are prohibitive to multimodalmodal access. The inclusion of visualization and simulation techniques within this area of research, along with the ability to interface these microscale analyses with regional travel modeling would add considerable value to this work.

### Residential Location Choice

Although considerable attention has been placed on the cross-sectional assessment of household travel in differing urban forms, little work has been done to address the underlying factors affecting residential location choice. Such inquiry is essential to begin to unravel the factors that underpin land use as a dynamic rather than static process.

A recent study conducted by Jonathan Levine at the University of Michigan revealed that Bostonians were more satisfied than Atlantans with the form and physical layout of their communities, identifying the level of walkability as a primary explanatory variable (Levine

2001). Boston has a highly heterogeneous urban form with many different types of land use patterns to choose from, facilitating a match between preferences and community type. Conversely, Atlanta is relatively homogeneous, with 82% of the population located in residential densities of less than four dwelling units per acre. Moreover, Atlanta has relatively few environments that are accessible on foot (Frank 2001).

Considerable opportunity exists to advance our understanding of the relationships between residential preferences and locational choice and activity patterns. The inclusion of a residential preference survey within a regional household activity survey provides the ability to assess the revealed travel choices and residential location choices against stated preferences. Although subject to the usual questions of content validity, tools such as element variation and conjoint method enable the development of trade-off models to gauge the interplay between travel time, locational choice, and other discrete factors embedded within a locational choice decision. This survey method can therefore provide an empirical basis to assess the degree of acceptance that various land use decisions would meet, and the likely benefits in terms of travel choice that they may garner. In addition, opportunity exists to assess the systematic relationships between perceptual and objective measures of urban form and how these measures predict household travel choice and activity patterns.

***Self-Selection***

"Self-selection" or community preference is emerging as a major topic of interest within land use and transportation research. One question in this arena involves whether people simply travel in a particular way because of who they are, rather than because of the physical environment in which they live. Those who believe it is "who we are" draw into question the generalization and even validity of findings from research on urban form and travel choice (Kitamura et al. 1994). Locational preferences, attitudes, and travel choices may well be inextricably linked. If so, it would seem all the more beneficial to gain a better understanding of the underlying preferences for differing residential environments. The ability to maximize the fit between one's expressed or underlying preferences and the revealed choices of a residential location is a function of the supply of a range of environments (walkable or auto-dependent) at different price points. Considerable evidence suggests that the vast majority of development over the past half century is auto-oriented (Eisenweiler 2001). Additional evidence from recent surveys suggests that preferences exist for denser more walkable environments (Meyers and Gearin 2002), inferring that a latent demand may exist to live in a place that enables one to walk more and drive less.

***Puget Sound Transportation Panel***

Unlike most other travel surveys, the Puget Sound Transportation Panel (1989–2000) is a longitudinal survey that attempts to retain households after a move takes place (Murakami and Watterson 1990). This survey design provides the opportunity to test the effects of different residential land use patterns on the travel choices of the same household at different points in time. A recent study of the households that moved and stayed in this survey found little variation in household travel choice after a move occurred (Krizek 2000). This finding can be interpreted in a variety of ways and leaves open the question over the degree of variability in urban form between locations chosen by a given survey household. Households that are more inclined to walk and take public transit may also be more likely to select a "walkable environment," given an affordable option that meets this criterion. However, moving is often associated with a change in life-cycle stage, income, or household structure. These factors can have an overwhelming impact on travel patterns confounding the ability to isolate the impact of changes in urban form on travel.

**Conveyance and Visualization**

Recent advances in the area of computer simulation and animation enable various approaches to site design, project development, and streetscape enhancements to be conveyed to lay audiences. This ability to translate research jargon into understandable information opens up a whole new set of opportunities to discover how specific land development and transportation investment proposals are received by the general public. Research is needed to gain a better understanding of the types of visualization techniques that are most effective at conveying quantitative and qualitative transportation and land use information within a spatial or "real world" context. Tools such as two- and three-dimensional images, axonometric projections, video simulation, and even audio overlay are widely available. However, care needs to be taken to ensure that these tools are used in a scientific manner to accurately convey results of research or to collect data in the form of responses from stakeholders, clients, or even recruited observations within a rigorous research design.

**Equity Considerations**

In their seminal work, *Access for All*, Schafer and Sclar (1980) outline the reality that land use has been used as a tool for segregation and underpins the opportunities for advancement experienced by a given population.[4] Following on this premise, research is required to assess the transportation related *benefits* and *burdens* of various approaches to land use and transportation investment at a variety of geographic scales. That is, measuring mix in terms of price points for residential products within the context of job access resulting from alternative transportation investments. The spatial mismatch hypothesis presented by John F. Kain more than 30 years ago (Kain 1968) remains valid (Sawicki and Moody 2000). Battles against "affordable housing" proximate to service sector employment in predominantly white suburban communities remains commonplace. Many of these suburban employment locations are not transit accessible, forcing cross-regional commutes in older highly polluting vehicles. Research testing the air quality benefits stemming from reduced VMT that could be achieved through the provision of a more heterogeneous housing policy could bear considerable fruit.

Representative data are needed to assess the travel and activity patterns of the traditionally underserved and how these patterns are related with urban form. Most regional household travel surveys are not representative of the lower income populations (Frank 2000).[5] These surveys are conducted through telephone recruitment protocols and do not capture the perspectives of individuals who are hard to reach (or those without a phone), have a language barrier, or harbor distrust for government. Therefore, extra steps need to be taken to capture these populations within our travel surveys. This will help us to understand their travel needs and the likely impacts they may experience from emerging transportation strategies. This is also important because value pricing and other demand management strategies can have a disproportionate impact on the travel patterns of the traditionally underserved.

## DATA NEEDS TO SUPPORT RESEARCH

Fundamental to assessing relationships between the built environment, travel choice, and environmental impacts are data availability and data reliability. This is an area where considerable improvement can be made through advancements in computing power and GIS software, which have opened up considerable new terrain for linking land use and transportation. However, in most instances the technology is far ahead of our ability to apply it. It can be argued that the primary factor limiting the application of more powerful computers and improved statistical and transportation modeling tools is data. Some of these data requirements are identified below within the context of specific land use and travel related considerations.

Recent advances in GIS software and computing capacity have enabled widespread usage of microscale data, namely, assessor's parcel-level land use data for transportation analysis purposes. Assessor's data are the foundation of property taxation within the United States (Moudon and Hubner 2000). However, the quality of the data available for transportation purposes remains limited. Enumerated here are suggested improvements to enable a more fruitful usage of parcel level land use data and digital photography within transportation research:

1. *Land use classification.* Improved accuracy, consistency, and legibility of the classification systems that designate particular land uses, including single family, retail, office, recreational, institutional, and other.The promotion of a single classification system that designates land uses across municipal boundaries is fundamental to conducting regional land use and transportation analysis. This is particularly necessary in regions such as Boston, where several local governments are each responsible for their own property assessments. The American Planning Association's recently developed land based classification system is a good place to start.
2. *Environmental considerations.* Increased accuracy of square footage, lot configuration, and the inclusion of first floor area as a predictor of impervious surface, runoff, and net-ground water recharge. Usage of multispectral photography captures tree canopy, building entrances, heat reflective spaces, and other predictors of urban heat islands.
3. *Microscale Environment.* Methods are required to integrate aspects of the microscale environment within travel behavior research. The increased resolution of digital photography enables the creation and application of computer software that can often measure building setbacks, sidewalk presence and width, crosswalks, build entrance orientation, surface parking, on-street parking, separation of pedestrian areas from vehicular areas, amount of street right-of-way per travel mode, and others.

Research funding is needed to test the benefits of these forms of data collection over current approaches and for the development of tools to apply these data within transportation planning research and practice.

## SPATIAL AND TEMPORAL ASPECTS OF TRAVEL

The widespread use of computer-aided telephone interviewing has somewhat standardized the collection of travel data.[6] In addition, travel data collection is being tied more frequently to land use through the collection of real world coordinates for places of residence and employment as well as the locations of trip ends.

### Travel Distances

The presence of these spatial locators enables the linkage between land use and travel to be established within a GIS environment. The distribution of activities in urban areas changes over very small distances. Advances in the ability to pinpoint the geocoordinates of travel destinations enables a far more accurate assessment of relationships between a particular travel choice (e.g., mode) and the urban form attributes of a given destination. Figure 2 is a parcel map showing the distribution of activities around a travel survey household in the Puget Sound Regional Council's 1999 Activity Survey. This graphic depicts a moderate degree of heterogeneity of land uses as well as a connected street grid─and close proximity to retail uses for this household. As a result of the type and specificity of the data that was used to create Figure 2, it is becoming feasible to test how the arrangement of land uses and street configurations at the microscale impact household travel. As such, trip-end information can be tied to parcel data to impute actual trip purposes and activity patterns.

**Travel Time**

Although the *spatial* accuracy of travel data has been dramatically improved, the *temporal* aspect of travel by means of self-reported travel times remains highly inaccurate (Pendyala and Pas 2000). The common reliance on self-reported starting and finishing travel times results in difficulties in estimating actual travel speeds and levels of congestion. This presents a considerable limitation in the ability to accurately capture the effects of increased density or mixed use on the performance of the transportation system within a given study area.[7] Recent advances in the usage of global positioning systems within travel data collection is enabling a more accurate estimate of travel speed, both by mode as well as per link in the transportation system. Global positioning systems also enables us to understand the actual route chosen for a given trip and assists in determining the extent and pattern of trip underreporting.

**Perception of Travel Time**

Travel choice is perhaps more directly related with the *perception* of travel time than *actual* travel time. The quality of the built environment can influence the choice to walk through its impact on our perception of the passage of time. As one moves through a space, perception of the level of interest in that space is a function of the rate at which the space changes or the "number of noticeable differences" experienced through movement (Rapoport 1987). Walking along a suburban arterial can seem endless because it was designed and scaled for vehicular movement. Time spent waiting for transit in a shelter may be perceived as more onerous than time spent moving slowly on a bus. Research that incorporates these perceptual aspects of travel time can greatly advance our understanding of how the environment affects travel choice. These improvements to travel data collection can support a great deal of new research intended to capture relationships between urban design and travel choice. For example, the likely increase in the reporting of short pedestrian trips will contribute to the creation of a multimodalmodal level of service measure. Ideally, such a methodology could capture the relative increases in utility for particular modes of travel resulting from various transportation investments and land use options. The collective increase in both spatial and temporal accuracy of travel data collection will no doubt provide considerable opportunities for vast improvements in the ability to link travel choice with urban form and suggest a wide variety of opportunities for research that were formerly not feasible.

**Relationships with Travel Choice**

Although these steps will support better land use data, there is considerable work that needs to be done to improve our understanding of how land use factors that can be obtained from better land use data relate to travel choice. Considerable work is needed to develop methodologies that address geographic scales of analysis at which different land use–travel choice relationships operate. For example, work and nonwork influences of urban form are quite different. To be meaningful in predicting work-related VMT, a jobs/housing balance measure would need to encompass a major area of a region. However, this same measure would be nearly meaningless for nonwork travel. Predicting nonwork travel choices, including mode, frequency, activity time, and diurnal or time-of-day considerations requires an assessment of smaller geographic areas around places of residence and employment. Beyond these questions of geographic scale, research is required to assess the interplay between specific aspects of land use. Several research questions that need to be addressed include

- Which combinations of uses and in what overall proportions provide the greatest degree of explanatory power for VMT, trip frequency, and modal choice within differing locational contexts and for specific travel purposes?
- How does the degree of dominance of a particular use, such as residential, retail, or employment, impact travel?
- How do perceptions differ from the objective ways in which we measure the level of walkability and the degree to which an environment is transit supportive?
- How does the arrangement of uses and the spacing between specific uses (e.g., corridor versus nodal clustering) at the neighborhood scale affect travel choice?

Hopefully, the application of other theoretical approaches to explaining human spatial behavior through urban form, such as landscape ecology (Forman and Wilson 1995; McHarg and Steiner 1998) and space syntax methods (Hillier 1996) will help to point the way toward other land use metrics that more accurately assess the implications of future transportation policy mandates.

## CONCLUSIONS

The recent birth of the term "transportation efficient" land use acknowledges a growing awareness among transportation, environmental, and other planning-related professionals of the role and effect of urban form and its impacts on human activity patterns.[8] The ever-increasing pressure to make more efficient use of environmental, fiscal, and health resources is no doubt a topic of growing interest as land, economic, and environmental resources continue to dwindle. At the macroscale, tools are needed that enable a better understanding of the region-wide impacts of transportation investments on locational choice and urban form. At the microscale, tools are also needed that address the relative impacts of alternative approaches to land development and transportation investment on travel, air quality, and public health.

Recent years have witnessed a growing awareness and interest in the ways in which the physical environment affects our behavior. Land use and transportation extend into several areas of growing concern for public policy and even popular interest. Robert Putnam's best selling book, *Bowling Alone: America's Declining Social Capital*, infers some provocative implications over how our land use and transportation policies might be affecting the social fabric of our culture (Putnam 2000).

Promoters of "smart growth" and "new urbanism" have expressed the need for better tools to predict the travel and air quality implications of specific land use actions and, moreover, the need to more effectively engage the local communities within planning decisions. Perhaps the single most important factor driving land use decisions today is the perception, or most often the misperception, on the part of the local community of the nature and the effect of a particular land use action. Therefore, considerable effort needs to be made to develop tools that provide the means to visualize for the community what a project will look like and how its relative impacts change with various adjustments to the program of development (Booth 2000). Not unlike most decision makers, the general public cares most about what affects them directly. Therefore, work is needed to gain a clearer understanding of how the built environment impacts one's health and quality of life, and how best to convey the findings of such work within local community decision-making processes.

*The following comment was received from a reviewer who provided comments as part of the institutional review process for this report. The resource paper primarily focuses on the topic of the linkage between land use and travel behavior. Within that topic the emphasis is on the issue of physical activity, whereas other issues, such as air quality and quality of life, receive less attention. Other land use and transportation topics that might be discussed, include:

- The impact of transportation investments on land use.
- The evolution of interest in the land use and transportation relationship.
- Federal policy influences on land use and transportation.
- Transit-oriented development.
- Beltway impact studies.
- Institutional issues of integrating land use and transportation planning.

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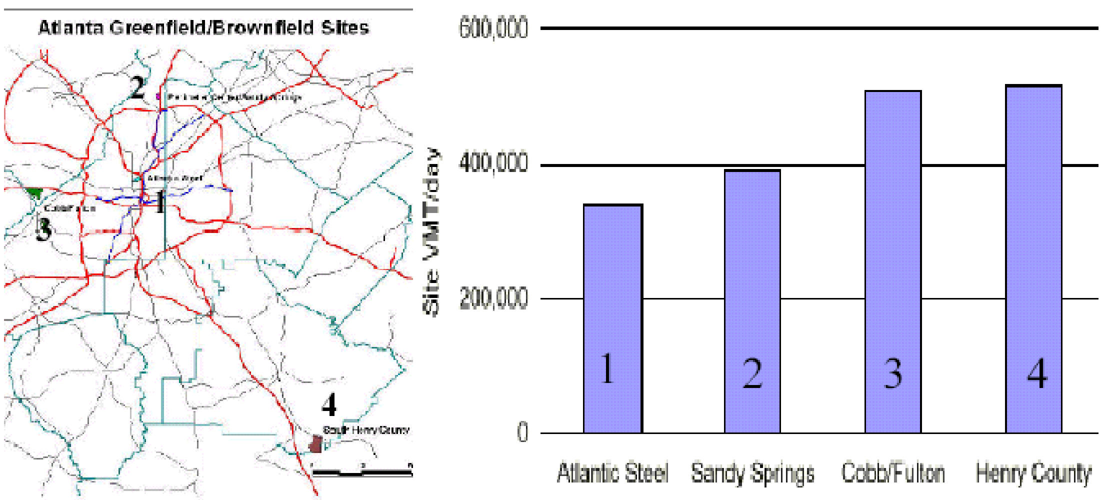
**FOOTNOTES**

1. Fast Food Nation, by Eric Schlosser (Schlosser 2000) documents the incredible influence of the fast food industry on American lifestyles and time-use patterns.
2. The longer-term economic impacts associated with the deployment of additional physical and social infrastructure to support outward growth on a per capita basis is considerable. Several studies have been done that document increased costs per person in association with exurban expansion (Burchell and Listokin 1978; Burchell 1998).
3. A TCM is programmatic or transportation investment action with a measurable long-term air quality benefit.
4. Such an argument is consistent with what is often proposed as the foundation of exclusionary zoning, dating back to "Euclid Ohio versus Ambler Realty," 1926.
5. Median incomes in the census were significantly lower than median incomes in regional household travel surveys in the Atlanta (1991) and Seattle (1996) regions.
6. As noted, the reliance on the telephone for data collection introduces other biases in the resulting data, including the lack of participation among lower income households that do not have a phone or are subject to language barriers.
7. Most major planning organizations currently measure traffic conditions through cordon counts and link-based vehicle traffic counts as opposed to reliance on household travel data.
8. Transportation-efficient land use patterns are thought to be those that are associated with reduced vehicle use. The recent birth of "location efficient mortgage programs sponsored by the Fannie Mae Foundation and the Center for Neighborhood Technology rest on the principal that household transportation costs and vehicle ownership are a function of transportation choices and neighborhood land use.

**FIGURE 1 Atlantic Steel regional location analysis (SOURCE: Bailly, H. and G. Anderson, U.S. Environmental Protection Agency).**

## Figure 1 – Atlantic Steel Regional Location Analysis




**Regional Emissions**

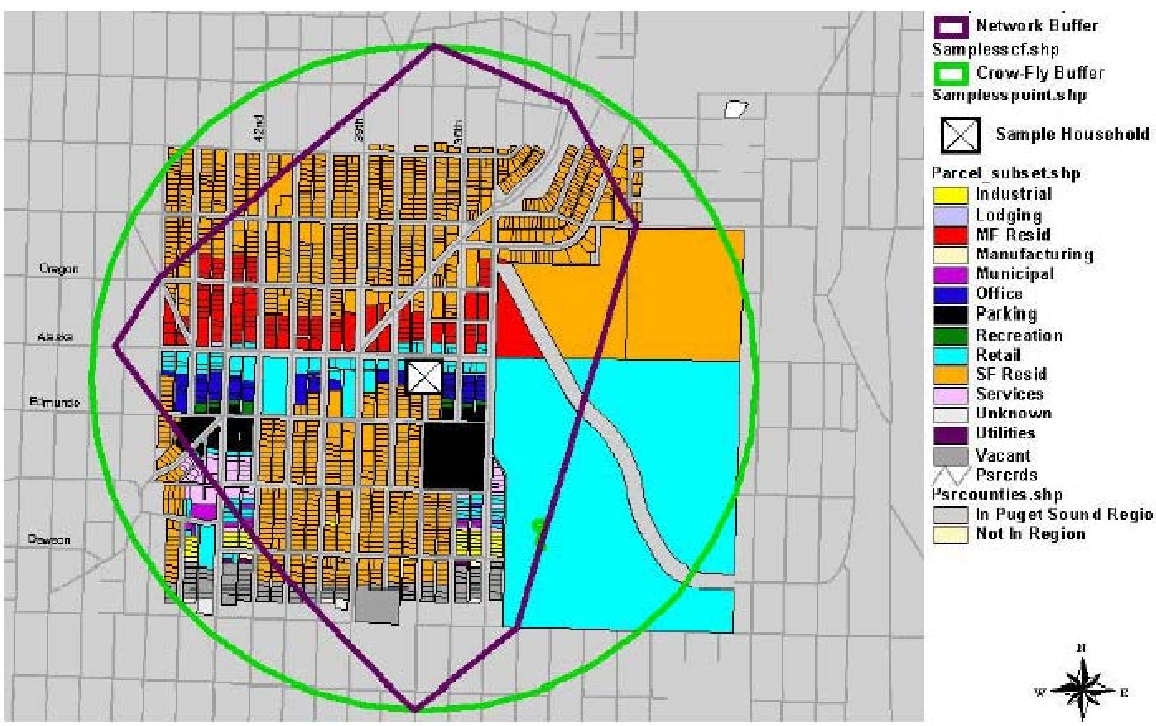
| | | NOx | | | VOC | | |
|---|---|---|---|---|---|---|---|
| | Site | Regional total (tons/day) | Associated with site (tons/day) | Site NOx difference from AS | Regional total (tons/day) | Associated with site (tons/day) | Site VOC difference from AS |
| 1 | Atlantic Steel | 191.95 | 0.400 | | 153.230 | -0.390 | |
| 2 | Sandy Springs | 192.10 | 0.548 | 37.00% | 154.374 | 0.754 | 293.33% |
| 3 | Cobb/Fulton | 192.24 | 0.690 | 72.50% | 154.312 | 0.692 | 277.44% |
| 4 | Henry County | 192.27 | 0.724 | 81.00% | 154.464 | 0.844 | 316.41% |

*Source: Hagler Bailly and Geoff Anderson, USEPA*

**FIGURE 2 Linking parcel data with travel behavior.**

*Figure 2 – Linking Parcel Data With Travel Behavior*



RESEARCH NEEDS STATEMENTS

# Land Use and Transportation

### 1. Implications of Habit Formation and Retention, and Perception of the Built Environment on Time Use, Travel Choice, and Location

**Problem Statement**

Researchers in fields such as environmental psychology, social learning, and public health have shown that human perception is a major shaper of behavior. Research is needed that explores the ability to transfer approaches from these disciplines to the understanding of the factors that influence travel and location choice. Ecological models used in public health explain factors that shape household- and person-level choices affecting human health. Decision-choice models used in environmental psychology predict how the built environment shapes perception and habits. Recent work on the interface between stated and revealed residential location and travel choice processes suggest that habit formation and retention may override the anticipated travel benefits that are assumed to be gained from more transportation-efficient approaches to land development. That is, households that do relocate to more transit-supportive environments often continue to drive for most of their daily activities, although it is not known how long this habit persists.

Approaches to explaining behavior from social learning and psychology have been successfully applied to guide programmatic efforts to improve health and the environment. Efforts to reduce cigarette smoking and to promote recycling have been successful in achieving their behavioral objectives through mechanisms that effect the perceptions of the American public about their quality of life. Research is required that tests the adaptability of these approaches to understanding habit formation and retention to travel and location choice through a variety of survey and other research methods. This research is particularly important to improve our understanding of the factors that influence the choice to walk and bike for both utilitarian and recreational purposes. Nonmotorized travel is particularly sensitive to the ways in which we perceive the quality of the built environment in terms of aesthetics, safety, comfort, social interaction, and other factors.

This research is supported through recent advances in activity-based modeling targeted at improving the understanding of actual distributions of time across activities located in space. Human perception and habit formation are not foreign to transportation. Level of service is defined by the Institute of Transportation Engineers as a function of the perceived relationships between travel time and distance. Through this interdisciplinary lens, the research can enrich the dimensions and even theoretical approaches through which travel and land use decisions are viewed and modeled.

**Proposed Research**

This research will test and apply research methods developed in other areas of inquiry focused on understanding human behavior through a set of tasks that would include a review of literature and experiences, development of strategies and opportunities for the transference of theoretical and applied models of behavioral research, proposed strategies for data collection, pilot survey design, conducting survey, data analysis, and recommendations for future research. Research components include:

1. A review of literature and best practices on the theoretical and applied approaches to modeling decision choice processes conducted within public health, social learning, environmental psychology, marketing, architecture and behavior, and other disciplines.
2. Assessment of the possible transference of these theoretical and applied approaches to understanding human behavior, researching and explaining travel behavior, and the land use decision-making processes.
3. Creation of a set of analytical approaches to adapt research design, survey research, and descriptive and inferential approaches to data analysis to travel data collection and urban form modeling exercises.
4. Preparation of an interim report that summarizes these steps and proposes a research design that includes primary data collection or other approaches to elaborate on other ongoing research efforts to test the effects of perception and habit formation and retention on travel choice in general and nonmotorized travel in particular.
5. Execution of research design based on feedback and review of original design.
6. Analysis of data collected in a manner that emphasizes analytical approaches developed within other disciplines and summarization of findings regarding implications of research on the understanding of the role of perception and habit formation on travel choice.
7. Development of a proposed agenda for future research to enhance the state of the practice on travel choice and residential location processes within the context of interdisciplinary exchange.

**Cost:** $800,000
**Duration:** 30 months

### 2. THE IMPACTS OF LOCATIONAL AND TRAVEL DECISIONS OF THE BABY BOOMER GENERATION ON FUTURE TRANSPORTATION AND LAND USE DECISIONS

**Problem Statement**
The baby boomer generation, the largest population group in the United States, has started to approach the retirement age (baby boomers are defined as those born between 1946 and 1963). As this group reaches retirement or empty nest status, members are beginning to make decisions that impact the land use and transportation landscape. Some attribute the increase in downtown development in some urban areas to the decision of boomers to move from typical suburban homes to urban homes that provide better access to cultural amenities and other services (such as health care providers). There are ongoing efforts in the real estate industry to evaluate these implications, but the focus does not include transportation-related impacts. More rural, tourist areas are also experiencing an increase in year-round retirees. Each of these examples raises a series of issues related to baby boomer retirement that may need to be addressed. Issues include (but are not limited to):

- Provision of adequate services,
- Change (or no change) in travel behavior and the provision of the proper transportation infrastructure to accommodate this behavior (e.g., transit, pedestrian facilities, etc.),

- The adequacy of services in suburban areas to accommodate older residents with limited auto opportunities,
- Provision of "life cycle" housing that allows residents to remain in the same community as they age,
- Safety,
- General public health (nonauto choices for older residents that improve their overall health),
- Nonwork trip choices of retirees and the impact on commute patterns,
- The possible reduction of travel and air pollution in metropolitan areas,
- The possible decline in the demand for older suburban housing stock,
- Other secondary and indirect land market impacts, and
- Availability of home and community-based health care services.

Long-term strategies will be needed if this group has the type of impact that some are predicting. It is also likely that the boomers will exert a high level of political power and have a strong influence on decision making. This work could anticipate some of the boomer needs and provide a longer implementation window. The research effort could also assess the potential length of these boomer impacts. If these changes will only be in place for 15 to 25 years (if at all), is that a timeline worthy of any major shifts in transportation and land use decision making or can this be viewed as an expected demographic factor for all future cohorts?

This demographic shift could be compared to the impact of women entering the labor market in large numbers in the 1970s and the emergence of two-job households. Research results could point toward the development of Smart Growth-type strategies (e.g., downtown housing development and 24-h activity) to address some of these emerging trends. Results could also be built into long-term local-, regional-, and state-level transportation planning.

**Proposed Research**

The research effort would include two steps:

1. Collection and compilation of available information, and
2. Synthesis of information to determine the transportation and land use results.

Research efforts would include a literature search on the locational decisions and travel behavior of baby boomers now entering retirement age (work by the Brookings Institute, Harvard University, and Sandra Rosenbloom could be a start). A key goal would be to determine if these choices and patterns seem to differ from other age groups or if they are simply a continuation of current activities. Other work could include a review of locational information of boomers that entered retirement age between the 1990 and 2000 census. Any household travel surveys (such as the National Personal Transportation Survey) that account for age could also be assessed for any decision changes. It would also be important to determine if the available data are "ripe" for analysis (do we need more boomers to reach retirement age to do this research?).

The research would also include a review of locational and travel patterns for retirees over the last 20 years. Has there been a shift in choices and life styles? Are these choices likely to be the same for the boomers or are the boomers (because of wealth, education, and societal advances) going to behave differently? If the boomer choices are the same as for previous retirees, then the impact reverts solely to the large cohort issue.

**Cost:** $200,000
**Duration:** 24 months

### 3. Implications of Goods Movement in Transportation and Land Use Planning

**Problem Statement**

Options for plant location, scale, and decentralization and the trend for movement to greenfield sites and smaller communities will accelerate as existing facilities become obsolete or are phased out.

The movement from traditional and transitional urban areas will impact the requirements of goods movement and, as a consequence, the requirements for use of transportation infrastructure. New roads (and railroads) may be required in areas where there is little, if any, commercial activity. Existing roads in these areas may be overloaded. Distribution manufacturing may reduce the distance finished (or in process) goods must be shipped. There will be opportunities for the development and use of innovative transportation equipment and services.

These factors will lead to changes in the nature of freight services. It is expected that there will be demand for smaller, more frequent services with potential increases in truck use that affects energy consumption, emissions, public safety, highway congestion, and road damage. Typically, however, the focus of transportation and land use planners is solely on goods movement by truck. Yet opportunities afforded by the creation of shortline railroads, construction of intermodal truck/rail and break-bulk terminals coupled with recent advances in logistics, and train scheduling provide attractive transportation alternatives that remain to be tapped.

The new generation of rail infrastructure is, at its essence, perfectly capable of fostering a wide range of versatile, responsive, and highly productive railroad operations. A fully variegated railroad system could be very responsive to appropriate classes of both new and traditional industrial users as well as the intercontinental customer. Specialized operations research and business analyses, however, are needed to move beyond the narrowly focused institutional models that wholly dominate major railroading corridors and do not address community goods movement.

The private versus public nature of rail and road infrastructure needs to be overcome, and rail companies need to be engaged in collaborative development of transportation and land use planning alternatives, both from an environmental and economic viewpoint.

**Proposed Research**

- Identify the kinds of industries and businesses that have the potential to relocate considering existing investments and access to clients and markets and incentives and constraints to dispersion of major employers, such as taxation, transportation, work force, and commodity factors.
- Project the dispersion of commuter travel and freight movement to suburbs, smaller cities, and other locations by time and type of location. Also, project the impact on existing cities, including reductions in congestion and emissions.
- Identify the induced freight requirements to service the businesses and supporting communities (foods, goods, etc.).

- Estimate the impact on transportation requirements for people and goods movement.
- Investigate case examples focusing on shipper profiles and business capabilities that could use and support the availability of intermodal or break-bulk terminals and shortline railroad operations.
- Prepare an overview of the regional and national impacts on energy consumption and emissions from industry location and modal choices.
- Identify the mix of hardware and operations technology improvements needed to optimize the integration of high-volume unit train operations with local intermodal, carload, and short train movements.

**Cost:** $500,000
**Duration:** 30 months

### 4. Impacts of Linking Transportation Infrastructure Investment to Development

**Problem Statement**
Land use planners have traditionally relied on a variety of tools and regulatory controls to manage land use and, most recently, to control "sprawl" associated with low-density residential and commercial land use. Many land use management tools in use today have their modern roots in comprehensive planning and zoning controls first developed in the early 20th century (U.S. Department of Commerce, Hoover Commission, 1923), and have based their approach to land use regulation and enforcement on a series of judicial decisions stemming from about the same period (Euclid v. Ambler, 1926).

Increasing post-World War II pressures of growth and development in metropolitan areas and the intensity of land consumption spurred by the economic expansion of the late 1980s and 1990s have spawned a more rigorous and proscriptive approach to addressing the overwhelming concerns associated with seemingly unrestricted expansion of metropolitan areas. Two approaches to managing sprawl have emerged that couple traditional comprehensive planning and zoning with the imposition of development fees and exactions, the coordination of transportation investments with land development, and the establishment of specific geographic "boundaries" for future growth. The traditional approach uses a "growth controls" approach that emerged in the early 1990s. A more programmatic response to sprawl using "growth management" principals (with the exception of the Portland Metropolitan area, which has had some form of growth management in place for more than 20 years) has been developed in response to the problems of multijurisdictional administration of growth controls.[1]

One of the most important aspects of these new growth management tools is the need for adequate public facilities (APF) regulations or concurrency. Under these requirements, jurisdictions subject to growth management policies must establish a standard of performance for various infrastructure components and then determine whether any proposed new development

[1] Growth controls, as distinguished from growth management, bear a striking resemblance to traditional planning practice. They are implemented with only local benefits in mind and without recognizing the "externalities" and imposition of costs of diverted development pressure on other communities in the region. Growth management takes a more regional view of accommodating growth; thereby seeking to avoid the inequities inherent in a patchwork of locally focused planning and establishing a broad context for managing future growth and development (Brookings Institution, February 2002).

exceeds these standards or might cause indirect effects in other communities subject to the jurisdiction of growth management provisions within the same region or state.[2]

Other states and local jurisdictions, although not explicitly embracing concepts of “growth management,” have implemented capital improvement programs or other infrastructure investment guidelines that attempt to link the location and timing of providing infrastructure with proposed land development. Many of these approaches have been introduced to correct past deficiencies in transportation investments, but often without understanding the relationship between project planning and implementation.

The problem with all of these approaches, especially as they have been severely tested by increased development pressure over the past decade, is that even in the presence of seemingly strong growth management systems, concurrency—especially where transportation investments have been required—has often been deferred or avoided. The result, from the standpoint of the transportation system, has been congestion, delays, and general dissatisfaction with both growth management and the ability of the transportation planning profession to “solve” the problems of mobility in the nation’s growing metropolitan areas.

**Proposed Research**

The proposed research would examine the current range of practice regarding concurrency requirements and other strategies or regional approaches to coordinated land use and transportation decision making under existing growth management regimes in place in metropolitan areas in the United States. Using measures of congestion, mobility, and accessibility, these areas would be evaluated with regard to the degree to which concurrency planning under growth management/control has addressed issues of congestion and the role of timely transportation infrastructure investments in meeting the concurrency requirements embodied in these growth management systems. Special care would be given to evaluating metropolitan areas ostensibly operating under a comprehensive “growth management” system versus those implementing more traditional “growth controls” coupled with nominal capital improvement programs or regional transportation improvement programs (TIPs).

The proposed research would include the following elements:

1. Review and synthesis of existing region- and statewide concurrency programs and metropolitan/local APF programs;
2. Identification of multimodal and nonmotorized concurrency required by existing statewide and regional concurrency and APF programs;
3. Selection of regions/states with APF and concurrency requirements that are prototypical of existing practice and development of case studies that describe the history, initial implementation, and current status of compliance with the originally intended regulatory requirements; and
4. Development and review of the state of the practice with regard to concurrency and APF requirements.

**Cost:** $425,000
**Duration:** 32 months

[2] The states of Washington and Florida require concurrency for all local governments that participate in the state’s growth management program. APF requirements are often easily ignored or circumvented by local governments. Both APF and concurrency require that public facilities be available concurrent with the impact of development.

## 5. Investigating the Disaggregate Travel Behavior Effects of the Built Environment

### Problem Statement

Increasingly, changes in neighborhood and commercial area design are being proposed and implemented in urban areas as solutions to transportation and environmental problems. Travel behavior varies depending on the design of the built environment at both ends of the trip. It is likewise affected by the quality and availability of transportation facilities and services, which connect trip ends. The extent to which proposed changes in land use mix, density, and improvements in connectivity between complementary uses (live, work, play) increase transit and nonmotorized travel, reduce auto dependence, improve air quality, reduce fuel consumption, and benefit public heath is clearly worthy of both further exploration and translation into better planning and analysis tools.

Research on the effects of the built environment on travel choice has become more sophisticated over the last decade and now includes many detailed forms of household-, person-, and trip-level analysis. However, further work is needed to refine and fill gaps in these analyses to make existing models more responsive and to develop new tools that more accurately predict travel and other effects of urban form. Improvements in our ability to assess land use and transportation relationships can be achieved both through recent gains in the quality of land use, travel, and transportation service data and through integration of these types of data in ways that are more comprehensive and readily consistent with available and developmental travel demand forecasting processes.

Advanced parcel-level data on the built environment need to be fully and jointly incorporated with disaggregate trip-level transportation data into analyses that predict how land use affects travel choice. Enhanced information ranging from microscale aspects of the built environment, on the one hand, to transportation system performance for peak, off-peak, and weekend travel on the other, is critical in better explaining travel behavior. The development of new and improved methods to incorporate these data into the travel demand modeling process is crucial for the creation of land use and transportation policies that will provide multiple favorable outcomes, including both mobility and health improvements.

### Proposed Research

The proposed research would quantify the effects of urban form and site design on a full range of travel behavior and related choices in context with fully described data on transportation service and the local built environment. The research would address the differences in revealed travel behavior related to the built environment at the locations where travel takes place.

*Phase I: Data Collection*

A review of research related to the built environment and transportation service variables should be conducted. Urban areas with up-to-date household-travel and employer-based surveys should be identified. It is anticipated that as many as three areas could be involved in the study to enable testing for transferability of results. Existing and further exploratory research on residential and commercial neighborhood morphology and its classifications would be undertaken to identify promising indicators for use in the analysis. A typology would then be developed to classify urban areas into neighborhood types. Travel survey and employer-based survey results would be gathered for the case study areas. Using the classification, the data would then be stratified by neighborhood type. It is desired that a statistically sound sample for the built environment types be obtained. It will most likely be necessary to conduct additional surveys to ensure adequate coverage of built environment types.

*Phase II: Analysis*
The analysis phase would advance the understanding and quantification of the effects that the built environment has on travel behavior. This analysis would be accomplished through the use of trip-level transportation service data in conjunction with disaggregate socio-economic data and other trip-end variables. Trip-end variables including accessibility as well as built environment variables should be considered in regional travel demand modeling. The most desirable analysis would address all urban modes of travel and the purpose of that travel.

Various data preparations would obviously be the first step, bringing together trip data, person data, full travel path transportation service data (distance, travel times broken down by component, user costs, trip quality measures, etc.), and the built environment indictors refined in Phase I. Exploratory steps would follow, applying an array of statistical analyses to better understanding interrelationships between the different indicators of the built environment and travel demand. For example, exploratory evaluation approaches could include an error analysis of application results for baseline travel demand models prepared without built environment factors, analyzing possible correlation of underestimating and overestimating the different steps of travel estimation to measures of individual aspects of the built environment. Aspects of travel demand to be examined should include auto ownership; trip generation; trip distribution; mode choice, including nonmotorized transport and auto occupancy; and possibly transit mode of access and other parameters.

With this background, further steps could move the research into specifying and testing demand model formulations actually containing a full array of built environment variables. Both richly specified models and models constrained to variables for forecast deserve exploration. This phase of research should not only seek to ultimately select and calibrate robust built environment variables, obtaining their statistics and coefficients, but also to derive built environment travel elasticity's for the various modes and purposes.

*Phase III: Travel Model Recommendations and Policy Implications*
Based on Phase I and II results, recommendations would be formulated for translating the research findings into transportation and land use survey technique enhancements and regional travel demand model improvements. These could range from new measures and predictors of the built environment (including a typology of urban forms for data collection) to methods to bring these and other land use measures into travel demand models, including current regional four-step models (trip generation, distribution, mode choice, and assignment), microscale models, and beta-testing of new activity-based travel models reflective of differentiation between first-order mobility choices and second-order travel choices, tour and trip structure, and other advancements.

Policy implications would be addressed based on the Phase I and II findings. Elasticitys for potential use in sketch planning applications could be extracted. It would be highly desirable to include in the Phase III activity the re-application of Phases I and II. This would abbreviate the developmental steps to a second and possibly a third urban region to address transferability issues. A document detailing the potential transportation, public health, environmental, land use policy, and analysis methods implications would be created.

**Cost:** $800,000
**Duration:** 3 years

### 6. PARKING STRATEGIES TO REDUCE ENVIRONMENTAL IMPACTS AND IMPROVE PLACE

**Problem Statement**

One of the most powerful factors reinforcing auto-dependent development and precluding alternative transportation modes is the prevailing assumption that all new suburban developments will be served by free parking. Furthermore, local governments' zoning codes generally require more than five parking spaces per 1,000 square feet of commercial development. Although these requirements can be justified on the basis that they protect surrounding neighborhoods from "spillover" parking, they may lead to excessive investment in parking. It is estimated that in urban areas, every vehicle will require between 5 and 10 parking spaces. Parking lots not only consume ever-increasing amounts of urban land that could be used for productive land uses, but they result in nonpoint source pollution that degrades water quality.

There are other costs associated with "free" parking. The "opportunity cost" of parking at an unmanaged lot, which the owner assumes has no land value, is estimated to cost $2 per parking space per day or approximately $500 per parking space per year. Structured parking will have substantially higher costs, but will still be given away for free. The availability of "free" parking may also bias the mode choice towards driving instead of using transit and other alternative modes of transportation.

Shoup and Willson have completed studies on parking pricing. Advocates of New Urbanism and other urban designers along with developers of mixed-projects have proposed designs that mask the impact of parking on the urban environment. Beyond these efforts, little research has been completed on the topic. Free parking is so widely accepted that little consideration has been given to changing public policies that could have a dramatic affect on urban form and transportation.

**Proposed Research**

This project will explore alternative strategies for addressing parking needs to reduce the intrusion of impervious surfaces on the landscape and its visual impacts and degradation of urban design. The research should address the following issues in parking policy, design, supply, configuration, and management:

- *Reduce environmental impacts*. A study of successful efforts to reduce the parking space requirements and associate impacts of runoff will be conducted. Case studies will be prepared of the various approaches, such as alternative parking configurations, smaller stall sizes, shared parking, reductions in total supply, and the development of structured parking.
- *Create more attractive and walkable places.* A survey of best practices in the design and management of parking will be conducted to show how to create more vibrant urban places with a pedestrian orientation, and how to develop policy instruments and improved planning practices for estimating parking demand and induced demand as a function of the price of parking. A combination of recognized municipal leaders, parking consultants, and parking authorities will

be polled to obtain leading edge examples where parking supply is used for multiple purposes, distributed throughout the development, and/or priced to encourage efficient use.

- *Estimate the true cost of parking.* The direct costs and indirect effects of parking will be developed. Direct costs include cost of building, maintaining parking lots, mitigation, and the associated cost of land. Indirect affects will include runoff and the associated water pollution and the impact on urban design and urban form.

**Cost:** $300,000
**Duration:** 18 months

## 7. Techniques for Integrating Local Comprehensive Plans into Regional Transportation Planning Processes

### Problem Statement

Regional planning has traditionally focused on transportation matters while local jurisdictions are the stewards of land use. Regions across the country are becoming more actively engaged with developing plans and strategies for integrating transportation and land use. However, many regional short- and long-term planning processes focus primarily on macro-level analysis and examine broad policy implications of transportation and land use decisions. A positive outcome from the integration of land use and transportation into regional plans is the establishment of new avenues for funding local land use projects. There are currently few planning tools and processes that address the integration of local comprehensive plans into regional planning. These tools and processes are helping communities address the transportation impacts related to increased growth while maintaining quality of life. We need these tools to quantify the impacts of local decisions on regional planning, help to prioritize these investments and link them to the regional vision, and provide the bottoms-up approach to regional planning that many local residents desire. Local comprehensive planning often leads to project-specific recommendations to address current and future transportation and land use needs. Because TIPs must be fiscally constrained, there is a need for local governments to work with the state and metropolitan planning organization or regional council to examine opportunities for funding these new project proposals. The development of these new “unfunded” projects often prompts discussion regarding whether and/or how to re-examine existing funding priorities in current TIPs. Many of these projects do not make it into regional capital improvement programs. One tool for incorporating these transportation improvements into the TIP is the practice of prioritizing projects in the TIP. This involves the weighting of transportation improvements that are sensitive to urban form into the current regional TIP. An examination is needed of the institutional arrangements that support the process of developing and approving local comprehensive plans, TIPs and Long Range Regional Transportation Plans.

### Proposed Research

This research project would focus on the development of four key components of integrating local comprehensive plans into the regional planning processes by

1. Examining the state of the practice for integrating local transportation and land use plans and policies into regional plans and models;

2. Identifying strategies that have been successfully used to address conflict resolution associated with incorporating competing local transportation and land use plans into a regional planning process;
3. Examining the state of the practice for developing critera for TIP project selection that is sensitive to urban form; and
4. Examining the institutional arrangements that support successful processes for developing, prioritizing and approving implementation documents such as local capital improvement plans, TIPs, and long-range transportation plans and state TIPs.

**Cost:** $350,000
**Duration:** 24 months

## Collaborative Research Needs Statements

### 8. Integrated Transportation and Land Use: Environmental Strategies for Sustainability

For full text, see Section 3.3 under Sustainability, Including Climate Change: Cause and Effects.

### 9. Technical Tools to Support Land Use Compatibility Planning

For full text, see Section 6 under Noise

# Noise

## WORK GROUP PARTICIPANTS

### Panel Moderators

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RESOURCE PAPER

# Noise

Gregg Fleming, *Volpe Center, U.S. Department of Transportation*
Ken Polcak, *Maryland State Highway Administration*

Nearly every person in the United States is affected by transportation-related noise. Transportation noise may affect the ability of people to carry on conversations, to concentrate at work and school, to sleep, and to enjoy recreational activities. Urban residents typically face the most substantial impacts; however, as airports are expanded and new ones are built, as ground-based infrastructure is expanded, and with the likely advent of high-speed rail in the United States, it is anticipated that impacts will continue to expand into suburban as well as rural communities well beyond the immediate vicinity of major cities. In addition, over the past decade noise in extremely low-level environments such as our national parks has become a major area of concern.

Over the past three to four decades much has been accomplished with regard to improving the noise environment in the United States, and there are many new technologies and approaches that offer the possibility of further improvements. Continued research in the area of transportation-related noise abatement is necessary to ensure that past accomplishments can be realized in the future. This background paper presents a brief historical perspective of past milestones in transportation-related noise control, along with a discussion of the more substantial on-going activities. It is meant to provide information for policymakers as they endeavor to determine how best to allocate continuously shrinking research funds. It is also meant to provide researchers with some thoughts regarding novel research areas for the future. For convenience, the three primary modal areas, aircraft, highway, and rail, are discussed separately. Recognizing that this is not only an era of shrinking research dollars, but a time in which transportation planning is increasingly involved on a cross-modal level, this paper also briefly discusses the need for resource sharing among different transportation agencies.

The field of transportation-related noise is relatively new. Significant work in the area began in the 1950s, mostly in the field of aircraft noise. Not coincidentally, the first commercial jet aircraft, the de Havilland Comet, was introduced in the first half of 1952, followed before the end of the decade by the Boeing 707 and Douglas DC8. By the late 1960s, more than 2,000 commercial jetliners were in operation worldwide (*1*). This rapid expansion fueled the initial rise in aircraft-related noise impact and mitigation research in the United States.

For the most part, the vast majority of early contributions in the field of transportation-related noise date back only to the 1960s and 1970s. For example, the first federal authority to control aviation noise was the 1968 amendment to the Federal Aviation Act, which directed the Federal Aviation Administration (FAA) to establish standards and regulations for aircraft noise in an effort to protect the public health and welfare (*2*). The most significant early work in the area of highway-related noise was performed in support of the National Cooperative Highway Research Program (NCHRP) between 1971 and 1976, which resulted in *NCHRP Reports 78*, *117, 144, 173,* and *174* (*3–7*) that established procedures and criteria for the prediction, evaluation, and abatement of highway traffic noise. Some of the most highly regarded research in the area of rail noise was also conducted in the 1970s.

**AIRCRAFT NOISE**

Over the past 25 years the FAA has addressed aircraft noise control through a concerted three-prong approach, which includes noise control at the source, control of noise through operational restrictions, and control of noise through effective land use planning (*8*). As aviation continues to be one of the most rapidly growing sectors in the U.S. economy, vigilance in pursuing this three-prong approach is critical. In its "Current Market Outlook for 2001," the Boeing Commercial Airplane Company estimated that the number of commercial jet aircraft in the United States would almost double by 2020.

With regard to noise control at the source, in 1969 the FAA issued the first version of Federal Aviation Regulation (FAR) Part 36 (*9*), which addresses requirements for aircraft noise certification in the United States. Since its initial release, more than 20 amendments to FAR have been issued to include coverage for virtually all types of aircraft. Several of these amendments also included increases in stringency requirements. The net result has been a substantial decrease in noise level for U.S. certificated aircraft. Some 25 dB of reduction in certified noise level has been achieved since the 1950s, which equates to an approximately 80% reduction in perceived loudness.

Careful examination of the trend line in aircraft noise levels over time indicates that the rate of reduction is slowing dramatically. In other words, the magnitude of the improvements in aircraft source noise technology appears to be shrinking with time. Currently, all indications are that this trend will likely remain for the foreseeable future.

Substantial improvements in aircraft/engine noise will only be realized through aggressive research initiatives. These initiatives will require substantial resources and knowledge, which can only be gained through continued government/industry partnerships, which have been the source of many gains achieved over the past four decades. Furthermore, the effects of noise-related design decisions on other important factors; for example, emissions, fuel burn, and economics, must be considered (e.g., there are important trade-offs between noise and $NO_X$ emissions).

The FAA has effectively compelled manufacturers to develop improved noise control technologies by imposing a mandatory phase-out of aircraft that did not meet certain noise limits. Most recently in January 2001, the Committee on Aviation and Environmental Protection of the International Civil Aviation Organization convened in Montreal, during which member states agreed to a new Chapter 4 noise limit, which will be a cumulative 10 dB below the current Chapter 3 limit. The member states are currently working on a proposal that focuses on the phase-out of noisier "hush kitted" aircraft. Continued research is necessary to ensure still further reductions.

In the area of noise control through operational restrictions, the FAA has embarked on several recent airspace redesigns with a primary emphasis on reducing the effects of noise.The main goal of such studies is to reroute backbone flight tracks to areas away from the general population, preferably over water, where possible. Comprehensive airspace redesigns have recently taken place in New Jersey and Illinois, and a third is being conducted in the Virginia–Maryland area. Advances in navigational technology such as global positioning systems make precise management of airspace much more of a reality.

There has also been a significant amount of work undertaken with regard to land use planning. FAR Part 150, which was officially issued at the end of 1984 (*10*), is the watershed document addressing aircraft noise-related land use planning issues. The FAA has dedicated a substantial budget to support noise remediation for residential structures located within areas of identified incompatible noise level; including land buyouts and extensive sound insulation programs. This activity will likely continue indefinitely. In a 1999 report, the U.S. General Accounting Office estimated that approximately $4.3 billion has been spent on aircraft noise mitigation programs at U.S. airports. Continued research is necessary to ensure that these funds are being spent properly and that the appropriate decision makers are adequately informed of available mitigation technologies. The FAA's Integrated Noise Model (*11,12*) is the tool used for Part 150 studies in the United States. Since 1978, the FAA has been committed to the long-term development and improvement of the model, a trend that is expected to continue well into the future.

It is also important to recognize the substantial accomplishments of the National Aeronautics and Space Administration (NASA) with regard to aircraft noise reduction. In 1993, with joint support from the FAA, NASA initiated an important 8-year effort known as the Advanced Subsonic Technology (AST) Noise Reduction Program (*13*). The program had a total budget of just over $200 million. This rather aggressive vision of the program was designed to ensure that there would be no increase in aircraft noise exposure in the 21st century. In terms of quantification, the program achieved its targeted noise reduction goal of 7 to 10 dB relative to 1992 technology. Similar to the previously mentioned FAA approach, the joint NASA/FAA program identified three target areas with regard to noise reduction technologies: source noise, noise control through operational restrictions, and land use planning.

The future of the NASA AST Noise Reduction Program is somewhat unclear. In 1998, however, NASA concluded that given appropriate resources to conduct the necessary research, a 10 dB reduction in aircraft noise exposure was attainable over the next 10 years; and a 20-dB reduction was possible within 25 years (personal communication, W. Willshire, May 1999).

There are several additional research efforts being conducted under the auspices of Society of Automotive Engineers Committee A-21 on aircraft noise (*14,15*). Currently, the committee is actively researching areas such as the lateral attenuation of aircraft noise, the atmospheric absorption of sound, computation of aircraft performance, and the determination of uncertainties associated with aircraft noise monitoring.

## HIGHWAY TRAFFIC NOISE

Much like the FAA and NASA, the Federal Highway Administration (FHWA) has also employed a similar three-prong approach to highway noise reduction, including control at the source, control through effective land use planning, and mitigation (*16*).

With regard to reduction of noise at the source, it is clear that improvements have been made. The emission levels developed in support of the FHWA Traffic Noise Model (TNM) (*17*) indicate that truck noise emissions at typical highway speeds have decreased by 3 dB since the last comprehensive national noise emission-level study was undertaken in the mid-1970s. Although a 3-dB decrease is barely perceptible to the human ear, it is important to point out that a 3-dB decrease in truck noise emission levels effectively offsets a doubling in U.S. truck population. Since the growth of the registered U.S. truck fleet has historically averaged approximately 3 to 4% per annum (*18*), the 3-dB decrease equates to approximately 18 to 23 years of growth without an associated increase in noise level. On the downside however, smaller vehicles in the automobile category have actually grown slightly noisier over the past two decades.This trend is more a function of the increasing number of sport utility vehicles and the higher RPMs that are typical of today's smaller cars however, rather than a lack of improvement in vehicle source noise technology.

What does the future hold in terms of vehicle source noise technology? In many ways air quality issues, and not necessarily noise, are the primary forces driving the development of future highway-based vehicle technologies. From the standpoint of energy efficiency, hybrid-electric vehicles appear to be the most promising in the short term, with hydrogen fuel cell technology being researched for a more long-term solution, in addition to vehicles powered by methanol, diesel, electricity, and compressed natural gas (*19*). With the exception of electric car technology, these approaches all use internal combustion engines and, therefore, offer little promise with regard to improvements in the noise environment in the vicinity of roadways. Electric vehicles offer some hope, at least for vehicles traveling at relatively modest speeds, where engine–exhaust noise is the primary contributor to the overall vehicle noise emission level. At speeds above about 30 mph, electric vehicles as well as other planned future technology offers little benefit with regard to noise, because as vehicle speeds increase, noise generated by tire–road interaction grows increasingly dominant as the primary contributor to the surrounding noise environment.

Certainly, control at the source is the most desirable noise mitigation approach. Given that most highway noise problems exist next to busy thoroughfares where typical speeds are in excess of 50 to 55 mph, it seems that a better understanding of tire–road noise is essential. For the past two decades tire–road noise has been a neglected area of research in the United States, with piecemeal work conducted by various universities, state highway agencies, and consulting firms. For a number of years, much more extensive and comprehensive research efforts related to tire–road noise have been conducted in a number of European, Scandinavian, and Asian countries. It is important that this work not be ignored, but rather should be drawn upon for insight and applicability in the United States. In this regard, things are looking quite promising. The United States appears to be at an important turning point with regard to tire–road noise research, with an increasing number of ongoing organized tire–road noise research efforts, probably the most notable being undertaken at the University of Texas (*20*), the Maryland State Highway Administration (*21*), the University of Central Florida (*22*), the Wisconsin Department of Transportation (*23*), and a recent study that was initiated by the California Department of Transportation. In addition, in 1998, Purdue University established the Institute for Safe, Quiet and Durable Highways. The goal of the Institute as noted in the charter is to "focus initially on developing a fundamental understanding of tire–road interaction noise and transferring this technology to practice. As the Institute grows, emphasis will be expanded to include traffic management strategies (e.g., night time speed limitations, use of intelligent transportation systems technology for identification, and removal of worst noise offenders, etc.) for quiet highway environments and other modes of transportation" (*24*).

As encouraging as the Institute and the charter are, there is only so much that can be accomplished in the area of tire–road noise. Based on past European research, reductions of as large as 10 dB may be realized (*25*). Reductions of that magnitude would certainly be considered a major accomplishment, but they would also come at a considerable cost and would require a fundamental change in the prevailing philosophy in the United States with regard to pavement design and construction. Unfortunately, even with such changes, it would by no means eliminate the highway noise problem.

Effective land use planning is another important component to successful reduction of the highway noise problem. Although noise-compatible development through effective land use planning and control is traditionally an area of local responsibility, it has become increasingly important for the states to encourage such consideration on the part of local governments. With the FHWA requirement, promulgated in 1995, that all states must establish and gain FHWA approval of a written "noise policy," some efforts have been undertaken to establish initiatives and incentives within the policies to encourage better land use planning at the local level. With limited resources and regulatory authority to mitigate impacts created by the introduction of incompatible development into existing noisy environments, "retrofit" solutions are less an option and prevention efforts are a much more essential part of the overall strategy.

The FHWA has established noise standards for different types of land use activities adjacent to highways (*16*). These standards require that for certain types of federally-aided highway projects, states must conduct noise analyses (as part of the National Environmental Policy Act process) to identify potential highway traffic noise impacts. If impacts are identified, noise abatement measures must be considered and implemented if determined to be both reasonable and feasible. Among the various types of possible abatement measures, the construction of noise barriers is the most commonly used.

Highway noise barrier construction will continue to be a growth area in the United States. As of 1998, the number of linear miles of barriers constructed in this country had doubled over the previous 5 years alone, eclipsing 2,610 linear miles by the end of 1998, and there are no signs that this trend will be significantly altered (*26*). Because of anticipated growth and because highway noise barriers typically cost approximately $1 million per linear mile, it is critical that highway noise barrier design be as efficient and cost-effective as possible. For this reason, in March 1998 the Federal Highway Administration (FHWA) released an entirely new, state-of-the-art computer program used for predicting the effects of noise in the vicinity of highways; the FHWA TNM (*27,28*). It uses advances in personal computer hardware and software to improve upon the accuracy and ease of modeling highway noise, including the effective, cost-efficient design of highway noise barriers. Since its initial release in 1998, there have been three updates, with a fourth soon to be released. The FHWA has mandated that by the end of 2002 the TNM should be the only computer program that may be used on Federal-Aid highway projects. Given that this program is being used to make multimillion dollar decisions, the FHWA is committed to the long-term maintenance development and upgrading of the TNM. This approach is very much in line with FAA's philosophy towards their Integrated Noise Model.

It is also important to note that the FHWA has demonstrated a substantial commitment to the improvement of their guidance and educational tools. In the past 5 years alone, the agency has released a guidance document on highway noise measurement (*29*), as well as two educational videos, one on highway noise barriers (*30*) and the on the acoustics of highway noise (*31*). In addition, in 2000, the FHWA released a suite of tools that will assist in the design and construction of noise barriers, including a manual on highway noise barrier design and an accompanying video and CD-ROM. All of these tools as well as many of the recommended enhancements to TNM have evolved from TRB research needs activities.

## RAIL NOISE

There have also been substantial accomplishments in the area of rail noise mitigation. These include the Federal Transit Administration's guidance manual, *Transit Noise and Vibration Impact Assessment* (*32*). This document provides the first standardized procedure for preparing noise and vibration sections for environmental compliance documents for transit projects. In addition, the Federal Railroad Administration is in the process of updating their rail noise measurement guidance document. Comprehensive research has also been conducted with regard to railroad horn noise. In particular, this research has examined such important issues as horn effectiveness and minimization of community noise impacts.

It can be expected that efforts will be initiated to incorporate a rail noise prediction module into the FHWA TNM. The TNM is essentially ready-made for a rail module. All of the propagation components encountered during a typical rail noise study are already included in TNM. The most substantial effort would likely be the development of a fundamental noise level database. This effort would likely entail a significant amount of work assembling and normalizing existing data, as well as collecting additional data. Resources would also have to be invested into the design and implementation of a user-friendly graphical user interface to support the module, and the development of an empirical algorithm for modeling source noise directivity.

Another important area, which is potentially on the verge of blossoming in the United States, is high-speed rail. All indications are that the substantial increases in security associated with air travels will lead to an increase in the popularity of rail travel, especially on the short-haul routes; for example, Boston-to-New York-to-Washington and San Francisco-to-Los Angeles. Currently, the Federal Railroad Administration is examining the possibility of introducing high-speed MAGLEV (magnetic levitation) technology into the U.S. market. This introduction will almost certainly lead to the need for research pertaining to the noise modeling and noise mitigation pertaining to this new technology. Similar to the situation involving tire–road noise, high-speed rail noise research has been conducted in Europe and Japan, where such systems currently exist. Efforts should endeavor to build upon what has already been learned, as well as expand specific research needs most applicable to the United States.

## SUMMARY

Will the future bring some "Holy Grail" of noise control technologies? It probably will not. More than likely, the coming years will be similar to those past, that is,grinding away at the problem, while accomplishing small incremental improvements along the way. However, these improvements cannot and will not be realized without a concerted U.S. research effort. The United States is facing stiff competition in the area of transportation-related noise research. Many other countries, particularly those in Europe, are outpacing us. Therefore, a concerted, unified noise-abatement research effort in the United States is necessary.

It is through this concerted, unified effort that we can accomplish two major objectives:

1. Build on past successes and accomplishments to more effectively advance the state of the art and state of knowledge in all areas of transportation-related noise, and
2. Develop a more cohesive and comprehensive approach in dealing with multimodal transportation noise assessment and abatement issues.

Substantial advancements have been made in transportation-related noise over the past 40 years. In addition, there are many promising, new activities currently ongoing in the field. TRB Committee A1F04 will continue to aggressively pursue its mission of research promotion and technology transfer in the area of transportation-related noise and vibration.

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RESEARCH NEEDS STATEMENTS

# Noise

## MULTIMODAL NOISE

### 1. A Cost-Benefit Analysis of Transportation Noise

**Problem Statement**
Although current and historical efforts to reduce transportation-related noise have been costly to develop, implement, and enforce, the nature and magnitude of their specific costs have not been well documented or accurately measured. As a consequence, policymakers may not have been thoroughly informed with regard to decisions on the design of noise-regulation and control strategies and the allocation of resources among different measures to reduce noise impacts. Maintaining support for the continued investment in noise-reduction technologies, including noise-modeling tools, and the development of effective noise-regulation strategies is contingent upon developing a more complete understanding of the costs of transportation noise, including the cost associated with further reductions on noise and the economic impacts of residual uncontrolled noise. In addition, it is imperative to understand the measurable benefits of an effective, well-rounded noise-control strategy, which includes elements of source noise control, operational techniques, and land use planning, including the design and development of accurate prediction tools

**Proposed Research**
The objective of the proposed study is to determine how past funds have been spent with regard to transportation noise reduction and to make recommendations on how to best allocate future funds, taking into account the potential benefits associated with particular decisions. The study will include a general account of past expenditures and a related evaluation of effectiveness. In short, the study will address the following three questions:

1. On what projects have noise-related funds been spent?;
2. How effective were these projects at accomplishing their goal of noise reduction; that is, what benefits were reaped?; and
3. How are future noise-related funds best spent?

In addition, this study will produce guidelines that will explain the process for conducting a noise cost-benefit analysis. This document will serve as a prototypical cost-benefit tool.

**Cost:** $400,000
**Duration:** 24 months

### 2. Development of a Methodology for Quantifying Transportation Noise Exposure in the United States

**Problem Statement**

Each year in the United States many millions of dollars are spent on reducing the exposure of Americans to various types of transportation noise, and many government efforts are directed at improving policies to manage transportation noise exposure. However, we have very little data on how many people are exposed to unwanted noise or how these exposures are varying over time. The last major studies to estimate noise exposure in the United States were conducted nearly 40 years ago. Politicians, decision makers, and the general public need this information to make informed decisions about improving transportation noise policies and spending public funds on noise-control projects. Thus, a real need exists for new studies to be conducted to estimate the current levels of noise exposure across the nation.

**Proposed Research**

It is proposed that a large-scale research program, using a combination of noise modeling and field noise measurements, be implemented to estimate the current levels of exposure of the U.S. population to aircraft, highway, and rail transit noise, and to forecast how these exposures are expected to change over the next several decades. Because of the size of this effort, however, it is proposed that a preliminary project be conducted to develop the research methodology and address various technical issues involved in implementing such a large-scale study. The results of the current effort would provide an assessment of the feasibility of quantifying transportation noise exposure and a detailed plan for conducting such a study.

**Cost:** $225,000
**Duration:** 24 months

### 3. Technical Tools to Support Land Use Compatibility Planning

**Problem Statement**

Land adjacent to airports, highways, and rail transit lines needs to be developed so that noise-sensitive uses are prohibited and community development is planned, designed, and constructed in such a way that transportation noise impacts are minimized. In the United States, the process used to support decision making regarding noise-sensitive land uses is referred to as land use compatibility planning. However, state and local governments often lack the technical capabilities necessary to successfully conduct noise compatible land use planning. Research is needed to develop capabilities that can be effectively applied to manage local growth and development with respect to transportation noise exposure. These tools should include educational materials, regulatory program guidelines, and the necessary technical and analytical capabilities required to properly conduct land use planning.

**Proposed Research**

The objective of this research would be to develop technical tools and educational materials that could be used by state and local officials and environmental planners in performing noise-compatible land use planning. Examples of information to be incorporated as part of the envisioned toolkit would include references to appropriate noise policies and American National Standards Institute (ANSI) standards regarding allowable noise exposures for various land uses and presentation of current "best practices" used by communities around the country. Examples of analytical capabilities to be incorporated into the toolkit include adequate noise-propagation models and Geographic Information System graphical representations of population distributions and existing land uses. This proposed project would result in a prototype land use compatibility planning toolkit ready for an initial test case involving land use planning in several representative communities and for various categories of transportation noise sources.

**Cost:** $250,000
**Duration:** 24 months

### 4. Synthesis of Noise Effects on Wildlife and Development of Impact Assessment Guidelines

**Problem Statement**
In considering the effects of transportation noise on areas adjacent to highways, airports, and railways, analysts normally give primary consideration to exterior areas of frequent human use. However, transportation noise can also adversely affect wildlife populations. Extensive studies of noise effects on wildlife have been conducted; however, an up-to-date compilation of related research does not exist. In addition, fundamental wildlife research is extremely costly, and the development of quantitative noise-dose and qualitative wildlife response relationships for a wide range of species is not economically or technically feasible. Information is needed on both the short- and the long-term effects of transportation noise disturbance on wildlife. However, knowledge gained to date could be used to develop general guidelines for assessing noise impacts on wildlife.

**Research Objective**
The objective of this study would be to compile the research conducted to date on the effects of noise on wildlife, with a specific emphasis on transportation noise. The effects of noise on different species will be examined. A comparison of work from various researchers studying the same species will also be included. A particular emphasis will be placed on the differing responses to varied transportation noise sources; for example, highway, aircraft, and rail. Based on a review of the compilation, general technical guidelines will be developed for assessing noise impacts on wildlife. These guidelines will take into account issues such as mortality, breeding periods, reproduction, changes in habits, abandonment, and other behavioral responses.

**Cost:** $325,000
**Duration:** 24 months

### 5. Study of Community Response to Nonaircraft Transportation Noise

**Problem Statement**
Current transportation noise policies in the United States rely heavily on scientific dose-response relationships between noise-exposure levels and various community responses, predominantly “community annoyance.” This is also the approach used in virtually every major country around the world and is a valid basis for environmental noise-management decisions. It is also the approach recommended by the World Health Organization in their recent report, “Guidelines for Community Noise” (WHO 2000). However, the database upon which the community annoyance

prediction curve used in the United States is based (published as ANSI Standard S12.9, Part 3) for the most part contains only aircraft noise data because community response data for highway and transit noise exposures are scarce. The current U.S. database and community annoyance prediction curve also does not address changes in noise exposure and the associated community response as a function of the time of day, although it is well known that transportation noise exposure and human activities vary greatly throughout the day. These types of data are needed to support future improvements in U.S. noise policies.

**Proposed Research**

It is proposed that a field research program be designed and implemented to assess community responses to highway and rail transit noise, and to investigate the effects of these exposures as they vary throughout the day. The data obtained from this research will then be used to develop community annoyance dose-response relationships for nonaircraft transportation modalities as a function of the time of day.

**Cost:** $750,000
**Duration:** 36 months

## 6. Development of Multimodal Noise Model Specifications

**Problem Statement**

As population growth and urban sprawl continues in the United States, our transportation infrastructure is continually expanding. Airport authorities are building new runways and adding terminals, interstate roadways are being widened, and new roads are being built. Rail corridors are being expanded and upgraded to meet the growing demand for regional transportation. The ever-expanding transportation infrastructure in the United States comes at a substantial cost to the environment, particularly in the area of noise. In a recent survey of the 50 major U.S. airports conducted by the General Accounting Office, it was concluded that noise is the primary environmental obstacle to growth, both now and in the future.

The traditional approach of conducting noise analyses separately by transportation mode is becoming more and more inappropriate. Conventional wisdom has historically dictated that if a noise study was being conducted near an airport, all one needed to do was conduct an Integrated Noise Model analysis. Similarly, for a highway noise study, use of TNM or its predecessor STAMINA was all that was needed. A substantial portion of the U.S. population is subject to the combined effects of noise from more than one type of transportation source. In many communities noise from aviation, highway, and rail systems are commonplace.

Unfortunately, there is currently no methodology for simultaneously assessing noise from aircraft, highway, and rail sources. This can result in inaccurate predictions of the noise environment at locations in the vicinity of multiple transportation sources. There is a recognized need for a Multimodal Noise Model (MNM), which can be used to compute the composite noise from multiple transportation sources.

**Research Objective**

The objective of an MNM would be to provide the noise analyst with an easy-to-use, seamless tool that would allow the assessment of noise impacts associated with integrated transportation corridors which include noise contributions from aircraft, highway, or rail sources. Most of the building blocks currently exist for the model, although development of a rail noise model compatible with the TNM would be necessary. The research should identify the necessary resources for model development. The final report should include a detailed description of (1) the MNM input/output requirements; (2) the MNM GUI, including sample user windows; and (3) the required modifications to TNM to support a rail noise-computational capability, including the identification and review of existing rail noise databases.

**Cost:** $150,000
**Duration:** 12 months

### 7. Simple Construction Site Noise-Prediction Procedure

**Problem Statement**

No longer can project proponents simply dismiss construction noise as a short-term necessary consequence. Today communities are more politically organized and regulatory agencies are more sensitized regarding the need to successfully mitigate construction noise, or else face the very real threat that distressed community groups may bring construction progress to an expensive and embarrassing halt. To enhance the state of the art of construction noise control, it is suggested that an improved construction noise-prediction model be developed. The model currently in general use today stems from old Environmental Protection Agency methods promulgated in the 1970s, which are based on noise-emission source strength levels associated with generic types of equipment. Shortcomings in the current model include existing equipment noise databases that are expressed only as maximum ($L_{max}$) broadband A-weighted emission levels, which oversimplify the importance of frequency (tonal) effects and does not address warning devices such as back-up alarms. The temporal (time-varying) changes in noise as equipment cycles through work operations are currently only estimated from acoustic usage factors, or the percentage of time that equipment is working at full power. Moreover, with better mufflers and engine housings, noise emissions associated with today's typical construction equipment have changed significantly over the past 30 years. Thus, the current method of modeling construction noise using metrics of interest, such as $L_{eq}$ or $L_{10}$ percentile levels, provides coarse estimates at best.

Fortunately, modern noise-measurement instrumentation, combined with the unique field data collection opportunities at numerous construction projects, provides an opportunity to quickly develop a much-improved construction equipment noise database and prediction model algorithm on a spectral basis. The frequency-dependent effects of noise barriers, distance and ground losses, atmospheric absorption, and interaction with structures or buildings can be modeled much more accurately. Defining a variety of generalized, process-related construction activities could potentially eliminate usage factors. Resulting construction noise predictions can still be evaluated against established noise-criteria limits, which are typically expressed in broadband (A-weighted) levels. It is envisioned that such a model can be developed in spreadsheet format using commonly available programs such as Excel or Lotus123, or as a new TNM module. Input geometries in the model could be graphical or tabular (as with TNM), and construction equipment of interest could be selected from database lookup menus.

**Proposed Research**

Develop a new construction equipment noise-spectral database and TNM prediction module.

**Cost:** $450,000
**Duration:** 24 months

## AIRCRAFT NOISE

### 8. AIRCRAFT NOISE HEALTH EFFECTS STUDY

**Problem Statement**
There has been a steadily increasing concern over the past two decades about the adverse effects of exposure to transportation noise on the health of exposed populations. The magnitude of these effects has not been fully determined nor have the cost of the effects. Most of the concern has focused primarily on potential cardiovascular effects (e.g., hypertension, myocardial infarctions, and arrhythmia) and immune system deficiencies. In addition, exposure to transportation noise and the existence of any of these medical problems may predispose individuals to a higher level of susceptibility to adverse physiological effects from other stressors, including exposure to occupational noise, other environmental noises, and nonnoise stressors. All of these concerns have been well documented in the scientific literature, mainly from studies conducted in Europe, and in the proceedings of various international scientific conferences, such as those sponsored by the International Congress on Biological Effects of Noise and the International Congress on Acoustics. The recent World Health Organization document, “Guidelines for Community Noise” (WHO 2000), also reported serious concern about the possibility of adverse effects of community noise exposure on human health and strongly recommended reductions in exposure to community noise, especially in or near large cities.

**Proposed Research**
The current project would develop the detailed methodology for a prospective epidemiological field study of aircraft noise health effects. Although various possible adverse health effects and different transportation noise sources can be studied using a variety of research designs, the recommended approach is to conduct prospective epidemiological study (i.e., a longitudinal field study) of possible cardiovascular effects due to exposure to high levels of aircraft noise. It is recommended that two groups of people living around major metropolitan airports (the exposed groups) and two control populations (the nonexposed control groups) be selected for inclusion in this study. It will be important to select the exposed and control groups so that there are differences in their aircraft noise-exposure levels, but that the total exposure to nonaircraft noise sources should be fairly similar. There should be at least a 20 dB DNL difference in the total annual aircraft noise exposure between the exposed and control groups, and less than a 5 dB DNL difference in exposure to other noise sources for these groups. Also, the subjects would need to be exposed to only the exposure levels that occur naturally in their environment to adequately protect the exposed subjects; that is, only casual exposure can be used, with no purposeful additional exposures being added during the study. Finally, expert epidemiologists would need to agree on the set of potential confounding personal ethnographic variables, which would need to be controlled through proper subject selection procedures. Examples of such

variables include age, sex, health habits such as smoking, and existing physical conditions such as obesity.

The subjects in this study should be followed for approximately 10 years, with annual physical examinations and health questionnaires. The data collected each year would be analyzed and interim reports published. At the end of the field study, reports on the study conclusions would be published and the noise policy implications of the findings would be discussed in a series of national forums.

**Cost:** $350,000
**Duration:** 10 years

### 9. Aircraft Community Noise Impact Below 65 dB DNL

**Problem Statement**
Long-standing noise-assessment methodologies for determining noise impacts from and community responses to aircraft flight operations have focused on areas within the 60 plus DNL areas and only consider noise from flight operations. These approaches have been successful in measuring and predicting both noise impacts and anticipating community response in those areas relatively close to the airport, where aircraft noise is typically the dominate noise source. Beyond those areas, however, where aircraft noise is not as significant, there is less understanding of the effects of aircraft noise and the impacts of changes in flight operations. In areas with lower aircraft noise impacts, slight changes in the number or path of flight operations may cause community responses that are not readily predicted or explained with current methodologies. These community responses may be due an increase in noise. They may also be motivated by an increased number of flights or changes in aircraft path and altitude, although with minimal changes in noise. To better understand community response to changes in aircraft operations resulting in levels below 60 DNL, more information is needed on the relationship between aircraft noise and the community's noise, flight frequency, and aircraft proximity.

**Proposed Research**
The objectives of this study are as follows:

1. Review available data from recent airspace and runway projects to determine the accuracy of predicted impacts and community response with actual results;
2. In light of the findings, evaluate the capabilities of impact predictions and recommend appropriate revisions; and
3. Identify and recommend appropriate new impact predictions.

The study would result in a technical report addressing issues related to community noise impact below 65 dB DNL.

**Cost:** $275,000
**Duration:** 18 months

### 10. Best Practices for Sound Insulation Around Airports

**Problem Statement**
Currently a large number of airports in the United States are either planning to implement sound insulation programs, engaged in conducting pilot sound insulation programs, or actively undertaking large-scale, continuing sound insulation programs. Although there is informal communication between these airport officials charged with implementing such programs, there is no formal guidance or best technological practices from those airports that are further along in their sound insulation programs to assist those airports just beginning such programs. In addition, most airports manage these programs in very different ways. There has been no assessment of what techniques work best in various situations, including how various airports measure the success of a specific insulation program. In addition, most sound insulation programs in the United States focus primarily on the use of new windows, new doors, and air conditioning, and little effort has gone into investigating more state-of-the art approaches to sound insulation.

**Proposed Research**
The objective of this research is to identify, categorize, assess, and document active sound insulation programs in the United States and other countries. This will include the identification of those elements of such programs that are most and the least effective. Similarly, it will include a review of the various approaches used by airports to quantify the success of their sound insulation programs, including a review and compilation of the testing methods used to field-measure the effectiveness of specific insulated residences. The review will also include a synopsis of local building codes, which regulate the insulation of structures in the vicinity of airports. This particular element of the review will focus on the applicability and technical accuracy and sufficiency of published codes. Based on a review of current practices, a guidance document will be prepared to assist airports in setting up, successfully managing, and quantifying the effectiveness of sound insulation programs. The guidance documentation will emphasize current state-of-the art techniques with a goal of identifying more promising techniques that require further investigation.

**Cost:** $425,000
**Duration:** 18 months

## 11. RESEARCH ON HELICOPTER NOISE IMPACTS TO THE COMMUNITY

**Problem Statement**
Helicopter noise is an increasing problem in the United States. Over the past several years, the FAA, under a mandate from the U.S. Congress, conducted a study of helicopter noise in urban environments in the United States, culminating in a Report to Congress on the state of helicopter noise in the United States. The study was of limited scope and hence the report was effectively a synopsis of research done to date. However, it included a comprehensive set of recommendations for additional research that is needed to better understand the helicopter noise issue. This needs statement focuses on recommendations in the report pertaining to research on various helicopter operational procedures as a noise-mitigation technique.

**Proposed Research**

As recommended for further research in the Report to Congress, this study would focus on the design and development of operational techniques and tools for mitigating helicopter noise. The target audience for these tools would be environmental planners, city planners, etc. The study would include a feasibility analysis of low-altitude aircraft tracking systems, the feasibility and expected effectiveness of an urban helicopter noise-monitoring system, and the development and documentation of quiet flying procedures for specific model helicopters that currently do not maintain such procedures. With regard to quiet flying procedures, the documentation would focus on specific models of helicopter in various regimes of flight.

**Cost:** $450,000
**Duration:** 24 months

## HIGHWAY NOISE

### 12. IMPROVE THE FEDERAL HIGHWAY ADMINISTRATION'S TRAFFIC NOISE MODEL EXPAND ACOUSTICAL CAPABILITIES

**Problem Statement**
Since the release of the FHWA Traffic Noise Model (TNM), users have identified additional factors that affect highway traffic noise prediction. Improvement of the model's acoustical capabilities will allow a more accurate and efficient analysis of traffic noise impacts and the development of more cost-effective noise mitigation.

**Proposed Research**
Develop acoustical improvements to the FHWA TNM and noise-analysis techniques that address the following requirements:

*Effects of Engine Compression Brakes*
Trucks traveling in the downhill direction, and those slowing down on level roadways, often use noisy engine compression brakes. However, heavy trucks traveling in the downhill direction are treated in the FHWA TNM in a manner similar to those on level roadways at constant speeds; that is, there is no correction to account for the noise increase due to the use of such brakes. The research will develop algorithms to account for the influences of these engine compression brakes.

*Effects of Structure-Reflected and Generated Noise*
Receptors adjacent to bridge structures are often subjected to undesirable noise levels, even after noise barriers are constructed on the structure. The cause of such noise is unclear; for example, does the noise result from vibration of the structure deck, does the noise result from factors related to different structure designs (open beam, box girder, reinforced concrete slab, etc.), or are other factors involved? The research will determine the mechanisms and/or sources of the noise emissions and if there are ways to mitigate the situation. Another issue relates to the degree of influence that may exist due to the open median area between parallel bridges and how this may influence overall noise levels. The research will determine the source or sources of noise/vibration emissions from bridge structures and quantify the differences that may be

associated with various bridge designs. Feasible mitigation measures and design approaches to minimize structure noise will be evaluated.

*Noise Associated with Weigh Stations, Rest Areas, Service Plazas, and Toll Facilities*
Traffic and activities in these areas affect adjacent property owners. Techniques need to be developed and evaluated to address noise-producing activities, such as truck idling, express lanes, tollbooth activities (including associated acceleration and deceleration), etc. The research will develop measurement and modeling techniques that accurately address noise associated with these activities.

*Effects of High Volumes of Trucks*
The FHWA TNM sometimes overpredicts noise levels adjacent to multilane roadways with high volumes of heavy trucks. It is felt that such overpredictions may result from a substantial number of vehicles being in the lanes farther from the receptor, thus being shielded by trucks traveling in the lane nearest to the receptor. Existing and future data will be evaluated to determine whether modifications to traffic noise-analysis techniques are necessary.

Improvements will allow for a more accurate and efficient analysis of noise impacts and development of more cost-effective noise mitigation.

**Cost:** $450,000
**Duration:** 36 months

### 13. Improve the Federal Highway Administration's Traffic Noise Model Through Additional Validation Studies

#### Problem Statement
The FHWA TNM is a state-of-the-art prediction model that is used to address many analytic complexities; for example, vehicle emissions, roadway geometry, and site characteristics. Validation studies are necessary to ensure accurate analysis of these complexities.

#### Proposed Research
Develop improvements to the FHWA TNM and traffic noise-analysis techniques to address the following:

*Effects of Irregular Terrain*
Highway sites may include terrain with undulations of varying size, with slopes to and from the roadway to the receiver, or with sharp discontinuities (cut or elevated roadway). There is a need to validate existing traffic noise-analysis techniques to ensure that irregular terrain effects are accurately considered.

*Vehicle Source Energy Distribution*
In the FHWA TNM, the total sound energy emitted by a vehicle source is apportioned between two subsources before being propagated out to receptors. There is a need to determine if there is a significant dependence of subsource-height relationships on vehicle speed, pavement types, graded versus level roadways, or interrupted-flow conditions.

Improvements will allow for a more accurate and efficient analysis of noise impacts and development of more cost-effective noise mitigation.

**Cost:** $300,000
**Duration:** 24 months

### 14. Understanding Tire–Pavement Noise-Generation Mechanisms

**Problem Statement**
European trials, which have concentrated primarily on pavement experiments, have found that a 10-dB reduction in noise generation is possible with some advanced porous highway and rubberized highway concepts. However, these investigations have been based on large-scale field tests with a limited number of alternatives. The tire carcass has been studied for its radiation characteristics. This aspect of the tire is reasonably well understood. There is some potential for developing a quieter tire in the frequency range below 500 Hz by building a tire that does not radiate sound effectively. However, the interaction of the tire and pavement has not been studied extensively, primarily because of the difficulty of making measurements in the contact patch region and partially because the behavior of the tire and pavement is difficult to model. Above 500 Hz, holography measurements indicate that the sound generation occurs largely at the entrance and exit of the tire–pavement contact patch. These mechanisms of noise generation are not well understood. If the mechanisms were better understood, it is possible that significantly quieter pavements, which are also durable, safe, and easy to construct, could be developed.

**Proposed Research**
Better understanding of the noise-generation mechanism is required. These mechanisms are believed to include air pumping, tread impact, tread release, and tread/pavement stiction. Laboratory studies are necessary to measure each of these mechanisms under controlled tire–pavement conditions. Measurements should be made of tread block motion, air pumping, dynamic pavement strain, and near-field acoustic radiation. Such testing is necessary on all types of pavement surfaces, including European quiet pavement alternatives.

The research effort should also consider the potential of European pavement technology for use in the United States. European construction approaches and materials do not directly translate to U.S. construction techniques or durability and safety standards. Adaptation and testing of these approaches for possible U.S. application is needed, and should include both laboratory and field testing.

**Cost:** $350,000
**Duration:** 36 months

### 15. Methodology to Measure the In-Situ (Natural) Acoustical Properties of Noise Barriers, Pavement, and Sound Propagation

**Problem Statement**
Recent advances in highway traffic noise-abatement capabilities and noise modeling have led to a greater need for descriptive measures of the acoustic properties of key site variables in the

vicinity of the highway. Such key site variables include the acoustical properties of the noise barrier, local ground properties, and acoustical properties of the road surfaces. Currently these variables cannot be measured *in-situ* using conventional methodologies, and are being approximated from laboratory testing or general trends reported in the literature. Furthermore, certain sound property measurements requiring "before" and "after" measurements are often imprecise because of the challenge of achieving source equivalence. Individual projects must rely on these data because there is no low-cost, practical method currently available. This leads to errors in prediction, which translates to inaccurate modeling of traffic noise, especially during the design of noise barriers.

**Proposed Research**
Develop instrumentation and methodology based on modern signal processing techniques to identify the key acoustical properties of a site needed for traffic noise prediction. Techniques are available for making these measurements during periods of heavy traffic flow because of the patterned impulse nature of the signal. The Reflective Index should provide needed information to allow for the determination of the important acoustical parameters, such as noise-barrier absorption and local ground impedance. With the proper equipment setup, these in-situ measurements supply important relationships between the results determined in laboratory testing and allow more exacting input to support new highway noise-prediction models in a practical way. Investigation will include

- Definition of the methodology required to perform in-situ measurements of the key acoustical properties of typical highway noise barriers, ground properties, and roadway surfaces, as well as the entire propagation path from source to receiver; and
- Testing of multiple sites should be done to allow for preliminary comparison of the results of the derived methodologies to the information now being used and to allow various wall textures and pavement surfaces to be tested. Specific instrumentation requirements and setup methodologies should be explored and documented during these field measurements.

**Cost:** $400,000
**Duration:** 24 months

### 16. ATMOSPHERIC EFFECTS ON HIGHWAY TRAFFIC NOISE PROPAGATION

**Problem Statement**
Studies by several research groups have shown that the atmospheric refraction and scattering effects that occur on the sound wave propagating from a highway traffic source is a source of error during prediction and measurement. It is possible for noise levels to change by as much as 10 dB or more at a receptor location due to these atmospheric effects. Because of a lack of research, the FHWA TNM only allows the user to input data for temperature and humidity. The existing FHWA modeling policy requires the use of neutral atmospheric conditions.

**Proposed Research**
Research is proposed to better quantify the atmospheric effects on highway traffic noise propagation and incorporate them into the FHWA TNM and measurement methodologies. The following tasks are proposed to accomplish the goals of this research:

1. Use existing data and/or perform measurements of noise levels at varying distances and heights from the vehicle path along with data of wind speed, wind direction, and temperature. Site geometry should be flat and open such that only ground effects, geometric spreading, and atmospherics would affect propagation. Normalization of ground effects and geometric spreading can be accomplished with the only remaining variable being atmospherics.
2. Using the measurement data from Task 1, along with data from other relevant studies, develop a prediction scheme.
3. Perform validation of the prediction scheme for traffic noise at two "real world" sites along existing highways, using the same methodology and set-up as used in Task 1.
4. Generate a final report documenting the measurement, prediction, and validation procedures, analyses, and results.

Funding this research would provide valuable information for the FHWA TNM, allowing increased prediction and calibration accuracy at greater distances from a highway than currently possible. This would increase the credibility of the analysis to the public and provide a more complete picture of traffic noise effects.

**Cost:** $300,000
**Duration:** 24 months

## 17. Develop a Methodology for Determining Tire–Pavement Noise Characteristics

### Problem Statement

Traffic noise negatively affects the quality of life for many communities adjacent to highways. Increasingly, communities are rejecting roadway capacity improvement projects, based in part on existing noise levels and on the perception that additional, noticeable noise will be generated by the project. The noise-generation characteristics of different types of pavements can vary as much as 6 to 9 dB.

A draft International Organization for Standardization (ISO) standard has been developed to measure tire–pavement noise in situ. This technique allows for quick evaluation of pavement and evaluation of the long-term noise-mitigation effects of quiet pavements. This ISO standard was developed without any U.S. testing. There is also no standard tire for noise testing using the ISO standard in the United States. Effort must be invested to identify a standard tire for use in tire–pavement noise testing. Testing must also be done to evaluate the ISO standard for application in the United States.

### Proposed Research

The research objectives should be to

1. Develop a standard tire for application in tire–pavement noise studies, and
2. Develop a standard method for testing the tire–pavement noise levels.

Tires manufactured for automobiles have many variations. Effort will be required to find a tire that is reasonably representative of the complete population and that reliably ranks pavement for tire–pavement noise characteristics.

The ISO standard for measuring tire–pavement noise is a trailer-borne microphone array referred to as the close proximity method (CPX). The data taken already in Europe and additional data from the United States will be evaluated to ensure that the CPX approach, or a U.S. alternative, is a reliable predictor of pass-by noise. An alternative using a sound intensity probe mounted to a vehicle to capture and analyze spectral data should also be considered.

**Cost:** $300,000
**Duration:** 36 months

### 18. Field Evaluation of Reflected Noise for Sensitive Receptors Across from a Nonabsorptive Noise Barrier Surface

**Problem Statement**
Residents on the opposite side of a highway from a reflective noise barrier often complain that construction of the barrier has increased noise levels in their area. The cause and nature of the perceived increase in noise levels is not fully understood.

**Proposed Research**
Comprehensive studies of noise-level magnitude, annoyance, and, in particular, 1/3 octave-band frequency analysis of the noise-source spectrum opposite a reflective noise barrier is recommended. These quantitative analyses will then be used to determine if the magnitude and/or composition of the noise level actually changes, or whether the complaints are triggered by the psychological phenomenon of "barrier envy" (nearby residents are not receiving a noise barrier when their neighbors do).

Several state departments of transportation (DOTs) should be canvassed where residents have complained about an increase in noise due to the presence of a recently constructed noise barrier across the highway. Using information about specific sites provided by the DOTs, study sites should be selected that provide equivalent cross-sectional topography and traffic operations for both target (across the highway from the reflective barrier) and reference (no barrier) locations. Data for comparative analyses should be simultaneously collected at various setback distances up to 1,000 feet from the roadway. Data should be collected for target locations near the center of the barrier and near the end of the barrier. Simultaneous data should be collected for reference locations under the same traffic conditions. A detailed record of meteorological conditions; for example, wind speed and atmospheric stability, should be maintained during data collection. Using annoyance metrics to identify image events, and especially 1/3 octave-band frequency analysis and meteorological data, traffic noise source and reflected spectra should be analyzed. Results should be assessed against current prediction methodologies. The analysis should identify whether or not a measured shift in the overall noise level and/or frequency content occurs for a given set of traffic operations. Evaluations should consider if the presence of a phenomenon varies with distance or is influenced by geometric or physical parameters such as barrier height and surface roughness, and by vehicle type and under variable traffic mix scenarios (i.e., high versus low truck percentages, low- versus high-speed traffic, etc.).

**Cost:** $300,000
**Duration:** 24 months

### 19. Improve the Graphical User Interface of the Federal Highway Administration's Traffic Noise Model

**Problem Statement**
The FHWA TNM is the current highway traffic noise-prediction model that incorporates state-of-the-art acoustical algorithms in a program with a Microsoft Windows environment and internal Computer-Aided Design Drawing capabilities. Since the release of FHWA TNM, users have gained training and experience in its use and have indicated a desire and need to improve the model's graphical user interface (GUI). Improvement of the model's software capabilities will allow a more accurate and efficient analysis of traffic noise impacts and development of more cost-effective noise mitigation.

**Proposed Research**
Develop improvements to the FHWA TNM that address user-identified GUI requirements. This effort will require extensive communication and coordination with FHWA TNM users and, if necessary, could require modifications of model source code. Improvements will allow a more efficient analysis.

**Cost:** $150,000
**Duration:** 12 months

### 20. Rumble Strip Noise Reduction

**Problem Statement**
As a safety measure many state highway agencies have installed rumble strips on paved shoulders of many highways. Designed to alert tired or inattentive drivers who have departed from the travel lane in time for them to safely recover, rumble strips can create an undesirable noise level at adjacent residential areas. Although there has been previous research on rumble strip noise levels, this was only to assess the level generated at a variety of distances away from the roadway. Ways to reduce the radiated noise levels from rumble strips while maintaining the necessary noise level interior to the vehicle needs to be investigated.

**Proposed Research**
The objective of this research project would be to identify alternative designs that could effectively alert errant drivers that they are leaving the travel lane without raising the noise levels at adjacent properties. Phase I would require in-situ measurement of the current design to establish a base line noise level, Phase II would test alternative designs under field conditions, Phase III would further test alternative designs under field conditions, and Phase IV would result in a report of the results.

**Cost:** $100,000
**Duration:** 12 months

### 21. Noise Barrier Costs

**Problem Statement**
Cost is a major element in the determination of the reasonableness of constructing a noise barrier. State decision makers use many factors in establishing barrier cost, and these factors may vary by state. Examples of this variation include the manner in which barrier costs are reported (e.g., lump sum, cost per square foot of barrier, and by individual construction items), and the effects of incidental items on cost (e.g., rights-of-way, utilities, landscaping, maintenance, drainage, safety, aesthetics, design, project mobilization, maintenance, and protection of traffic).

**Proposed Research**
A synthesis is necessary to identify the factors that decision makers use in determining noise barrier cost. The synthesis should lead to development of best practice guidance for barrier cost determination.

Funding this research would provide valuable guidance to those involved in evaluating noise barrier reasonableness. This would increase the credibility of the analysis and the evaluation techniques.

**Cost:** $100,000
**Duration:** 12 months

## RAIL AND TRANSIT NOISE

### 22. Directive Transit Vehicle Warning Systems

**Problem Statement**
Transit vehicular warning horns are relatively omni-directional and can be a source of annoyance in areas of the community adjacent to rail lines. For example, train horns sounded before grade crossings can have significant impact on nearby neighborhoods. In some cases whistle bans have been enacted, but with the unfortunate consequence of increased accidents. More directive horns can "focus" the sound toward the ideal target area while minimizing community impact in other directions.

**Proposed Research**
Design and demonstrate examples of directive warning systems for locomotives and transit vehicles consisting of phased arrays of horns using well-established array theory. Establish practical trade-offs between the degree of directivity achieved, ruggedness, and cost. These designs can then be assessed both theoretically and empirically in terms of community noise reduction so that they can provide standard measures, including $L_{max}$, SEL, $L_{eq,}$ and DNL for a variety of transit vehicles.

**Cost:** $250,000
**Duration:** 18 months

### 23. Data Synthesis for Vibration Insertion Loss Afforded Tie and Ballast Trackwork with Ballast Mats, Tie Boots, and Trenches

**Problem Statement**

On a national scale, increased emphasis is being placed on expansion and refurbishment of fixed-guideway transit systems, especially steel rail–steel wheel formats. This has exacerbated the need for accurate information regarding effective methods of reducing the potential adverse effects of transit-induced ground vibration. Many existing rail transit systems are in close proximity to dense residential and other vibration-sensitive development. New rail systems that are in the planning, development, and design stages are often located in urban environments very close to vibration-sensitive use. This juxtaposition of seemingly incompatible use is not "encroachment" in the traditional sense; it is actually desirable and necessary to place these systems adjacent to and within origin and destination uses such as residences, medical facilities and high-tech research and development facilities, and manufacturing areas. The ability to co-locate transit systems with origin and destination uses that do not create unacceptable adverse ground-borne vibration or noise is increasingly important.

Although the efficacy of the most sophisticated (and most expensive) vibration-isolation systems such as floating-slab are well documented, there is a definite need for access to comprehensive information regarding the performance and applicability of the more practical alternatives of using ballast mats, tie boots, and trenching methods of vibration isolation. This will allow the system designers, environmental analysts, funding agencies, and the affected public a better understanding of the overall effects of the rail transit system and the cost-benefit aspects of providing a transit system that is compatible with vibration-sensitive uses.

**Proposed Research**

Research would synthesize a comprehensive database addressing initial and long-term technical effectiveness, initial and life-cycle costs, construction concerns and delay mechanisms, and applicability preferences of using ballast mats, tie boots, and/or trenching approaches to vibration isolation of rail transit systems. The synthesis could include a meta-analysis of existing research and where new research might be required, especially in regard to performance characteristics of candidate mitigation options in various soil types.

**Cost:** $75,000
**Duration:** 9 months

### 24. Vibration Dose-Response Curve Development

**Problem Statement**

Vibration propagation through the ground is physically very similar to the propagation of noise through the air. Vibration and noise are similar in other respects as well; however, the criteria by which scientists judge the acceptability of noise and vibration are quite different. For example, environmental noise is typically judged on the basis of cumulative noise exposure using the Day Night Average Noise Level (DNL) metric. The DNL is essentially a 24-h average with a 10-dB nighttime penalty to account for people's increased sensitivity to noise at night. The well-known "Schultz" curve is a dose-response relationship between airborne sound levels and the percentage of people highly annoyed. This curve forms the basis for the expected change in noise impact due to either increasing noise level or the frequency of occurrence and duration of noise events. However, the vibration impacts of transportation projects are assessed solely on the basis of maximum vibration level and do not generally take into account the frequency of occurrence of the events. Attitudinal surveys for vibration effects, similar to surveys used in the Schultz curve development, would be required to develop such a vibration dose-response curve.

**Proposed Research**
Develop a dose-response curve for vibration and ground-borne noise to assess the change in annoyance due to a change in the frequency of occurrence and duration of vibration events.

**Cost:** $500,000
**Duration:** 24 months

### 25. Transit Warning Signal Dose-Response Data Development

**Problem Statement**
The specific noise issue in the vicinity of at-grade rail crossings is locomotive warning horn and crossing bell sounds, which cause significant noise impacts. The acoustic signatures of these warning devices are unlike the transportation vehicle exposures that are the basis for the dose-response surveys that guide most judgments of environmental noise acceptability. For horn soundings, the distance to the 65 dBA DNL noise contour can extend as far as 1,000 feet from the grade crossing and can encompass a large number of homes. Crossing bells, although not reaching as far into the community as warning horns are still a substantial source of annoyance and complaints from nearby neighbors. It appears that existing criteria do not adequately reflect the potential adverse effects caused by these sources.

**Proposed Research**
The dose-response data upon which the Schultz curve and its variations are based do not include locomotive warning horn or crossing bell noise. This is a shortcoming in the basis for assessment of transit project noise impacts. It could be, for example, that the "startle effect" of warning horns would result in a 1 dBA allowable increase. Or perhaps the DNL is the wrong metric to use. A comprehensive attitudinal survey/noise-measurement program should be conducted to address these issues.

**Cost:** $230,000
**Duration:** 12 months

### 26. Program for Reducing the Noise from Corrugations in Transit Rails

**Problem Statement**
The operation of steel-wheeled transit vehicles on steel rails may develop short-pitch corrugation of the rails. The interaction of the wheels rolling over the corrugated rails generates noise with a tonal component, which is usually harsh and uncomfortable for transit patrons and obtrusive to wayside receivers, and has been associated with the “singing rail” condition. Several variables may contribute to the development of corrugation including rail car suspension components, wheel composition and resonance characteristics, rail metallurgy, tie spacing (both average distance apart and variation), tie composition, tie or rail fixation, roadbed composition, and possibly other unknown elements. Rail corrugation eventually reaches the point where noise

exceeds reasonable levels and the nearby community complains. Current practice is to remove rail corrugation by grinding the rail to restore the original profile. On some rail transit properties, a more sophisticated grinding program is followed, which uses multiple profiles to equalize the wear across the wheel tread, and special profiles for curves, which also reduce wheel wear. This program, where rails are ground every 2 to 3 years, reduces corrugation and controls rutting of the wheel tread. However, maintenance costs would be reduced if a design solution or preventive measures besides rail grinding could be found.

**Proposed Research**
Significant research into this topic has been conducted and is ongoing elsewhere in the world. A first objective in the United States should be to evaluate the state of research elsewhere and determine its applicability to U.S. needs. U.S. research resources can then be aimed at building on existing research and integrating these efforts towards achieving solutions. In general, this research should be directed towards determining the causative relationships of various design parameters or conditions that contribute to short-pitch rail corrugation. These include track support stiffness, lateral stiffness, damping properties, tie spacing, wheel resonance, rail and wheel metallurgy, and tie characteristics. This substantial effort will result in the development of efficient and effective design approaches and methods for preventing corrugations.

**Cost:** $500,000
**Duration:** 36 months

### 27. TRANSFER MOBILITY MEASUREMENTS AND TESTING TECHNIQUES

**Problem Statement**
Transfer mobility measurements are used to help predict vibration and ground-borne noise impacts from transit and rail systems and also to evaluate the effectiveness of vibration mitigation techniques. Current methods for measuring transfer mobility between planned or existing transit facilities and nearby sensitive receivers present a number of problems. For example, high background vibration levels in busy urban environments make such measurements and analysis difficult and time consuming. Existing required measurement equipment is cumbersome and often presents logistical roadblocks. Newer, less burdensome measurement techniques need to be investigated.

**Proposed Research**
Investigate and recommend acceptable test parameters of current test methods such as required signal coherence, and explore newer alternative test methods such as Maximum Length Sequence technology to reduce time and expense with improved measurement quality.

**Cost:** $75,000
**Duration:** 6 months

### 28. NOISE AND VIBRATION FROM AUTOMATED PEOPLE-MOVERS

**Problem Statement**

More than 100 automated people-movers (APMs) of various kinds and sizes now operate around the world. Urban planners, engineers, and architects often consider using APMs to link activity nodes and serve remote parking and transit. They have little data on actual experience with noise and vibration from APMs. This discourages them from considering APMs in general and also from specific applications, which integrate stations and guideways into urban buildings. A better understanding of the noise and vibration characteristics of APMs may lead to their more widespread use.

**Proposed Research**
Define a sample range of APMs and collect consistent, objective data on noise and vibrations (some of which may already exist) in a form useful to planners, engineers, and architects. Compare these findings with light rail transit, heavy rail transit, bus, and other forms of public transport. Produce a user-friendly database and guidebook.

**Cost:** $125,000
**Duration:** 12 month

# Sustainability, Including Climate Change: Cause and Effects

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RESOURCE PAPER

# Sustainability, Including Climate Change: Cause and Effects

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The terms "sustainable development" and "sustainability" have come to encompass a wide variety of environmental, economic, and social concerns. An often-cited definition of sustainable development comes from the 1987 Brundtland Commission (United Nations World Commission on Environment and Development).

> A sustainable condition for this planet is one in which there is stability for both social and physical systems, achieved through meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Notions of sustainable development have become associated with a wide array of issues and public policy concerns. Although these applications have often been related in their fundamental emphasis on ensuring a habitable planet, some have focused more on ecological and natural resource needs for achieving this goal, whereas others have stressed the social and economic dimensions of this goal. In transportation, the 1997 National Research Council–Transportation Research Board (NRC–TRB) report, *Toward a Sustainable Transportation Future*, employed a more conservative approach, focusing on disturbances that threaten large and irreversible environmental consequences.

A broader view is now emerging. The World Bank, in a 1996 report on transportation, articulated this broader definition well, identifying three components:

1. Economic and financial—includes the issues of adequacy of transportation infrastructure funding, organization, and scale.
2. Environmental and ecological—includes issues of how transportation investments and mode options influence travel and land use patterns and how these in turn influence energy consumption, emissions, air and water quality, and habitats.
3. Social—emphasizes adequate access to transportation services by all segments of society.

A forthcoming (2002) NRC/TRB report from the Surface Transportation Environmental Cooperative Research Program Advisory Board embraces this broader approach.

In practice, though, sustainability does not lend itself to a precise definition. It is used here, as elsewhere, to signal a more desirable future, in its broader sense. However, even this reference to a more desirable future raises questions: are we speaking of a future that is no worse than today's, implied by the word sustainability, or are we speaking of an better future. Most would say we should aim for a better future.

## Context: Some Success, More Challenges

The United States has enjoyed a remarkable, prolonged period of economic expansion since World War II. The standard of living for the average American has increased substantially, aided by continuing transportation improvements. Population has also grown substantially, increasing by 130 million in the past 50 years. This economic and population growth has led to even more rapid expansion in travel.

Automobiles, trucks, and highways have been the dominant means of surface transportation in the United States throughout this period and have played important roles in supporting and shaping the nation's growth and expansion. They have heavily influenced our consumer goods economy, development patterns, and popular culture. Access to a private vehicle has become the rule rather than the exception for those of driving age, and today more than 95% of our person-trips are by automobile. Truck usage also has grown and now accounts for more than 90% of all shipments. The distances traveled also are increasing. Since 1970, Americans have more than doubled total vehicular travel, and truck travel has more than tripled, with annual vehicle travel by heavy combination trucks nearly quadrupling in that 30-year period. In the United States, there are now more than 200 million vehicles traveling 5 trillion miles per year.

This increased travel translates to increased accessibility, mobility, and economic activity, which is largely beneficial. However, it imposes large direct and indirect costs on society.

The direct costs for expansion of the transportation system have been significant, with considerable investment in infrastructure, facilities, vehicles, and energy. However, even with this huge investment, many urban transportation facilities have become or are becoming even more congested. Much valuable time is lost in heavy traffic and more energy is consumed.

The indirect effects are becoming increasingly troubling. The population growth of more than 130 million in the last 50 years has been largely accommodated on the urban–suburban fringe; consuming land formerly devoted to farms, ranches, forests, and range. In addition, many center cities have lost population as household size decreased and living space expectations increased. More travel also threatens safety and environmental quality.In addition, because it relies so heavily on the use of private vehicles, some segments of society are find themselves marginalized (the percentage of households without cars dropped to only 8% in 1995, but those without cars are even more marginalized than before because of fewer transitoptions).

These indirect effects include increasing dependence on insecure petroleum sources, increasing emissions of greenhouse gases, more pollution sources, and greater ecological threats. Transportation already accounts for approximately two-thirds of the petroleum consumed in the country, and the amount continues to increase as we travel more in larger vehicles. Greenhouse gas emissions fromtransportation in the United States continue to grow and are expected to more than double in the next half-century. Highway safety has improved significantly; however, 40,000 people continue to be killed in crashes annually (motor vehicle crashes are the seventh leading cause of death nationwide). Roads connect all parcels of land in the country and are estimated to affect the ecology of more than one-fifth of the nation's land area. The high reliance on the private vehicle for travel along with population growth, fewer persons per dwelling, and increased housing space per individual, have been significant contributing factors in the broad spread of urbanized land areas. The amount of land devoted to residential and commercial land, parking, and streets is increasing at a far faster rate than population, although it is important to note that road mileage is increasing only 0.2% per year.

In addition, whereas increasing reliance on private vehicles provides greater access to an increasing proportion of the population, it marginalizes others. Indeed, the costs of owning and operating personal vehicles consumes 19% of the average American household's income—equal to the amount spent on food and clothing combined, and triple that for medical care. Not all can afford to own and operate their own vehicles, and some cannot drive. Approximately 8 million households are currently without vehicles and these are often smaller households with older people, often women, living alone. A substantial proportion comes from among disadvantaged minority populations, often immigrants, living in center cities. New York City alone accounts for a significant segment of the non-car-owning population. In center cities, the number of households without vehicles can reach as high as 40% among minorities. People who cannot drive have limited access to jobs, services, education, and recreation. Older people, low-income people, and minorities bear a disproportionate share of these adverse impacts.

In summary, heavy auto use and the outward expansion of metropolitan areas, although improving mobility for many and offering opportunities for better and lower-cost housing, create a broad range of threats: air and water pollution, waste disposal, heavy energy use, fragmented farmlands and habitat, and community disruption. In turn, these problems can adversely affect ecosystem health. The overall quality of life improves for some, but disadvantages result for others.

An effect that is particularly challenging and merits special attention is climate change. It is a unique problem for the U.S. transportation sector because it is now recognized that actions taken here in the United States are likely to have important environmental (and economic) implications elsewhere. The U.S. transportation sector as a whole accounts for about 5% of all the $CO_2$ emitted by human activities worldwide. Although this percentage appears modest; however, no other energy use sector in the United States or elsewhere in the world accounts for a significantly larger portion of global $CO_2$ emissions. The challenge of creating institutions and mechanisms for reducing greenhouse gases affects virtually all activities and requires not only regional and national cooperation, but international cooperation as well.

Concerns about energy, the environment, safety, and social impacts have led to the enactment and creation of a wide variety of national and state laws, rules, and institutions, including the National Environmental Policy Act of 1969, Clean Air and Clean Water Acts as amended, Corporate Average Fuel Economy standards, California's Zero Emission Vehicle mandate, Federal Environmental Justice programs, and various rulemaking by the National Highway and Transportation Safety Administration. The provisions of successive Federal-Aid Highway Acts, especially the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), have called for stronger roles for metropolitan planning; systematic consideration of social, economic, and environmental effects; protection of parklands; and more public engagement in planning. Certainly progress has been made in mitigating the adverse consequences of motorization and expanded transportation activity; the air and water are cleaner, species have been protected, accident rates have been reduced, and many other adverse impacts have been avoided or mitigated.

However, these policies have not yet produced what could be labeled a "sustainable" transportation system. Many indicators are headed in the wrong direction. Traffic congestion, energy use, and greenhouse gas emissions have worsened as population, vehicle size, and travel increased. Concerted efforts to improve and expand public transportation in recent decades have slowed and even reversed in many communities; but even so, only about one-half of the communities in the United States have public transportation systems, and the country as a whole has the lowest share of transit use of all the advanced economies, at only 2% of total travel.

The strains and challenges confronting the transport sector will be aggravated in the future. Unlike most other industrialized countries, the United States is expecting continued population growth. The U.S. population is predicted to grow by 60 million in the next 25 years (close to 1% per year), with most of that growth in metropolitan areas. Annual passenger-miles traveled are predicted to increase even faster than the population or the economy, swelling from 5 trillion miles in 2000 to 8.4 trillion miles in 2025. Conversely, the number of roads and lane-miles of roads are expected to grow very slowly. Transit use, although expected to grow, is not expected to keep pace with population growth.

## TOWARD A RESEARCH AGENDA

As the 2002 National Research Council–TRB report observes, "Our nation's collective vision of a transportation system that is efficient, equitable, and environmentally benign is clear. But we have no strategy to get there." The nation must find ways to deliver a transportation system that simultaneously promotes economic growth, adds to the health of communities and individuals, is safe, uses energy efficiently, and enhances the natural environment.

New approaches will certainly be needed. The congestion, air pollution, and energy dependence of current approaches already impose high costs on the nation's global competitiveness, economic security, and human and environmental health. Growth will add to the challenges and innovative responses will be needed if we are to maintain and improve the quality of life for all Americans.

Emerging technologies, regulatory actions, policy innovations, travel behavior changes, and new planning processes offer significant opportunities for improvement. Some options are obvious to transportation professionals, but those with greater impact require a sea change in public attitude. Our decentralized democratic style of government and our embrace of individualistic freedom undermine many changes that have large social benefit, but inhibit personal desires. In any case, relatively little is known about the practical application of these options and whether and where they will succeed.

In a broader sense, there is incomplete knowledge within the scientific and social science fields about the extent to which humans are changing the natural and social environment and the long-term implications of these changes on the well being of future generations. Considerable more attention and resources are needed to examine the trade-offs between benefits and costs and the most desirable strategies for enhancing the transportation system.

The 2002 NRC–TRB Advisory Board report concludes [draft]:

> We need a better understanding of vehicle and fuel technologies, highway design and operations, travel behavior, development patterns, and their environmental consequences. We need improved methods for analysis, forecasting, and other decision support tools. We need to improve and alter methods of finance, environmental education, and management systems. We need to modify institutions and regulatory approaches, and in some cases create entirely new ones, to deal with newly prominent problems such as climate change and to effectively manage rapidly changing technologies and fuels. We need to devise ways to mitigate the environmental harm that has already occurred from past practices, and to improve the environmental performance of future actions. More broadly, we need to study the effects of alternative approaches in transportation, land development, and the environment, and to document their efficacy. Finally, we need to put the

findings of research into practice and create a system of continual improvement through renewed research and its implementation.

The 2002 [Draft] Advisory Board report lays out six critical research areas in transportation and the environment: human health impacts, effects on nature, land use/transportation issues, effects of new technologies, distribution issues, and planning and institutional issues.

The Advisory Board has concluded, based on its review of the situation, that the current state of knowledge and the tools available for environmental assessment are inadequate to the tasks ahead. They are failing the urgent test of assuring informed and effective decisions on transportation and the environment. Briefly stated, the Advisory Board finds that

- The scale of investment in environmental research related to surface transportation is far too small in relation to the scale of transportation activity and its impacts.
- Coordination of the research that does take place is insufficient to get the greatest benefit from the research effort or to ensure that gaps in the research agenda are filled.
- The dissemination of research results is inadequate and the practical implementation of research findings is too slow, with the result that current practice is not up to date and opportunities for improved performance are being missed.
- A long-term strategy for systematically addressing the effects of transportation on the environment has not been fully developed or implemented; current policies and investment strategies have tended to focus on short-term solutions.

The stakes are too high to continue to accept the status quo. Just as in the past, the major transportation system investments and private sector land-development activities occurring today will become fixtures in the landscape and economy of the nation. Better information and better methods are needed to support intelligent policy and investment decisions in the near term, as well as the long term. Failure to improve our knowledge and policies may result in significant and long-lasting damage to our nation's human, economic, and environmental well being. Investment in research and its implementation offers real promise for improved performance of our transportation systems.

## CONCLUSIONS

The 2002 NRC–TRB Advisory Board articulated the need for a well-funded, coordinated environmental research agenda. The United States has been a leader in vehicle and fuel technology, highway system development, and carpooling and vanpooling innovations, but it lags behind in other important ways, and continues to fall short of creating an environmentally sound transportation system.

The transportation community must become more engaged in working through metropolitan planning organizations, the elected officials serving on their boards, and the many related groups concerned with pollution, environmental justice, energy use, land consumption, and social community with related interests. Sustainable transportation, in all its dimensions, has remained a national policy issue and recently emerged as a global issue. Unfortunately, the planning and development community as well as transportation planning research has not adequately engaged questions of "sustainability." This workshop offers a unique opportunity to link researchers and practitioners in an endeavor to forge a U.S. agenda that will focus research, realign practice, and position institutions to become major players in critical transportation issues of the new millennium.

RESEARCH NEEDS STATEMENTS

# Sustainability, Including Climate Change: Cause and Effects

## 1. What Is the Responsibility of the Surface Transportation Sector for Sustainability?

**Problem Statement**

Although much is known about the effects of surface transportation on greenhouse gas emissions and climate changes, much less information is available upon which to measure its impact on other indices of sustainability. Some would argue that there is little agreement as to the appropriate measures or definitions of sustainability itself. However, the idea of sustainability is increasingly coming to be understood as a collective process for considered decision making and action and not simply a particular end-state or outcome. There is a growing consensus that sustainability must include economic betterment and social equity, not just a narrow technical focus on greenhouse gases or other aspects of the natural and human environment.

Transportation professionals are being asked to implement projects and programs that are responsive to issues and policies outside their normal realm and that may serve multiple policy objectives under the banner of sustainability. Research is needed to help transportation officials and policymakers better understand the connection between the surface transportation system and public policy goals that extend beyond motorist safety, air quality, traffic flow, and environmental protection.

**Proposed Research**

As a first step towards developing this better understanding, research is necessary to document examples of sustainable development initiatives that have incorporated transportation projects and programs, both in the United States and within the international community. This review would provide a broad overview of the ways in which transportation is being used as a tool to achieve more sustainable communities and should focus on identifying

- Measures and indices of sustainability that incorporate transportation, and
- Transportation projects and programs that have been adopted in response to policies aimed at achieving sustainable development.

As a second step, U.S. best practices will be presented as case studies. The case studies will identify common elements among successes, pitfalls to avoid, and detailed evaluations. Examples of case studies may include:

*Maryland Smart Growth*—The state of Maryland implemented a comprehensive smart growth program in 1997 designed to ensure that state resources were focused in planned growth areas. It is seen as a model program in the United States, but its effectiveness has not been evaluated.

*New York Quality Communities Program*—The state of New York has developed a Quality Communities initiative to encourage infill development and urban renewal within its cities and towns. Although comprehensive in scope, the program has not been evaluated for its environmental or preservation benefits.

**Cost:** $300,000
**Duration:** 18 months

**2. IMPLICATIONS OF CLIMATE CHANGES ON INFRASTRUCTURE: TRANSPORT AND POTENTIAL ADAPTATIONS TO CLIMATE CHANGES**

**Problem Statement**
A growing body of research is documenting the possible effects of climate changes on the United States and the world. A National Assessment conducted by the U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change,* discusses a range of potential impacts including changes in temperature, shifts in precipitation rates, the increasing frequency and severity of storms, and melting permafrost. The national assessment process has so far included 17 regional assessments that examine the potential effects of climate changes on various regions of the country, as well as five sectoral assessments. Although changes in climate, water levels, storm activity, and other effects will each have important implications for transportation infrastructure and operations, little research has yet been conducted to explore these effects, which vary by location. There are numerous studies that could be conducted to examine potential impacts on transportation and possible adaptation strategies to avoid or minimize these effects.

**Proposed Research**
The proposed research would examine the potential effects of climate changes on transportation networks, drawing from the scenarios developed by the U.S. Global Change Research Program's National Assessment, the Intergovernmental Panel on Climate Change, and other scientific research. The research would be conducted as a series of case studies. Each case study would focus on a different region of the United States (e.g., Great Lakes, southeastern coast, Alaska) and/or the effects on a particular mode or service component of the nation's transportation system (e.g., flooding of critical highway and transit facilities, potentially reduced aviation safety and reliability, pavement durability, and marine freight). The studies would include a review of the potential climate changes, and the probability of these changes, based on available science. The impact of these potential climate changes on the transportation element will be assessed. The case studies will include

- An analysis of the implications of the climate changes on the transportation elements in the region/mode under discussion, including an analysis of the associated risks and costs.
- A discussion of potential adaptation strategies that could be considered by transportation agencies and regional planners.
- An examination of how potential adaptation strategies and redesign could be accomplished consistent with other environmental goals.

**Cost:** $200,000 per case study
**Duration:** 12 months per case study

## 3. Strategies for Greenhouse Gas Reduction

### Problem Statement

Human activity is generating increasing amounts of carbon dioxide and other greenhouse gases (GHGs), with possible evidence that this buildup is altering climate. Considerable effort is being devoted to understanding the relationship between GHG emissions and climate change, but relatively little to the relationship between transportation and GHG emissions, especially in the United States. Europe and Japan are ahead in developing an understanding of the nature of the contributions of their transportation systems to the potential global warming phenomena and of the potential strategies that are available or that could be developed to lessen GHG emissions. Strategies may be grouped into those targeted at transportation technology, fuels, travel behavior, and land use. The strategies that are most effective are those that include a mix of policies and initiatives. The mix and specifics of the actions taken will vary considerably from one region to another, depending on local institutions, resources, economic activities, and cultures.

A two-phase program is proposed: The first phase provides an overall framework and the second is an analysis of cross-cutting strategies.

### Phase One: Overall Framework

### Proposed Research

The first step in phase one is to document what is known about the contribution of different components of the transport sector to climate change, as disaggregated as possible. Then a framework should be developed to specify the amount of reduction possible in different activities and with different initiatives. This framework would reflect what is known about demand elasticities, technological progress, and the linkage of GHG reduction strategies with other social goals (including pollution reduction, petroleum import reduction, public financing constraints, public health, and urban livability). This framework should identify opportunities for action at the local, state, and federal level.

**Cost:** $200,000
**Duration:** 12 months

### Phase Two: Analysis of Cross-Cutting Strategies for Green House Gas Reduction

Virtually all effective GHG reduction strategies include technology, behavioral, and institutional elements. Research is needed that considers synergies, interrelationships, and indirect impacts and benefits. Under the direction of a single program manager, four separate research projects are to be conducted.

### 3. 1. Vehicle Technology and Fuels

**Problem Statement** Alternatives to petroleum fuels and internal combustion engines are becoming more compelling. Imported fuels now account for more than one-half of all consumption, and approximately two-thirds of this petroleum is used for transportation. Motor vehicles, using internal combustion engines, operate almost exclusively on petroleum fuels (approximately 97% dependent), contribute about one-half the air pollution in urban areas, and account for more than one-fifth of all GHGs emitted in the United States. With calls for more environmentally benign vehicles and fuels intensifying, and rapid innovation in propulsion technologies, major changes are about to happen. Better understanding is needed of the choices and pathways of change. An improved knowledge of these technologies and their impacts would inform the policy process with respect to pollution, energy use, energy choices, and climate change. Government and the public should seek to be well informed to ensure that environmental factors are adequately considered in the development, evolution, and use of these products. The challenge is to complement and not duplicate industrial research and development.

**Proposed Research** Knowledge is needed to inform public strategies for diesel engines, hydrogen fuel, fuel cells, and a variety of other options. For example, diesel fuels and engines have higher emissions of nitrogen oxides and particulate matter than gasoline combustion, but substantially lower GHG emissions and energy consumption. How large are these effects? Likewise, hydrogen and fuel cells are widely seen as the dominant fuel and vehicle propulsion technology of the future, partially because of their superior environmental attributes. Better understandings are needed of the costs and benefits, the role of public policy in developing new fuel distribution systems, and the role of public policy in aiding the transition to environmentally beneficial fuels and vehicles.

Because of the especially broad cross-cutting nature of a hydrogen path, it is recommended that special attention be given to hydrogen. Energy systems of the future will likely use hydrogen and electricity as the energy carriers, probably integrated into a single system. The implications are broad and cut across many industries and activities. The implications for the transport sector are huge—for fuel distribution, vehicle design and use, fuel and vehicle supplier industries, vehicle maintenance, and vehicle attributes. Eventually, it is expected that vehicles would be powered by fuel cells that operate on hydrogen, and likely integrated into stationary energy systems. Such a system, transitioning eventually to hydrogen made from solar and other renewable sources, would essentially eliminate emissions of air pollutants and GHGs, and reduce international tensions that result from competition for limited petroleum supplies. However, the transition path to a hydrogen economy is unclear. Many different paths may be followed, with different economic, environmental, social, and political implications. Substantial research is already underway in the private sector—on developing better fuel cells for vehicles and electricity production, better hydrogen storage containers, and better hydrogen production processes. Ongoing public research is needed to guide public investments in research and development, support basic research (industry under-invests in these technologies and fuels because a large share of the benefits are market externalities), investigate environmental benefits and costs, inform policies addressing fuel and vehicle safety, air pollution, GHGs, and energy dependence. Research is also needed to anticipate issues associated with the integration of mobile and stationary energy production (e.g., connecting fuel cell vehicles into the electricity grid) and the development of hydrogen fuel distribution systems that might be linked with electricity supply systems.

**Cost:** $300,000
**Duration:** 24 months

### 3.2. Demand Management Strategies for Greenhouse Gas Reduction and Sustainability

**Problem Statement** For several decades, growth in vehicle miles of travel (VMT) has exceeded growth in both the number of households and population, and most forecasts assume that this upward trend will continue unless public policy intervenes. Demand management is one strategy for reducing VMT growth and therefore GHG emissions (and related problems of congestion and air pollutant emissions). Demand management strategies promote the use of alternative modes or reduce the number or length of trips, thus reducing VMT. Specific strategies include the promotion of transit, ridesharing, biking, and walking, as well as telecommuting, teleconferencing, teleshopping, and pricing strategies. Demand management strategies would be linked with initiatives that introduce new vehicle and fuel technologies, new intelligent transportation technologies, new mobility services, and land use management and planning. Although travel alternatives and trip reduction strategies have been widely implemented, few studies have explicitly considered their impact on GHG emissions and broader sustainability efforts. Some modes have not received as much attention as others. For example, bicycling and walking are quiet, efficient, nonpolluting, healthy, economical, and desirable, yet planning for bicycling and walking is often limited by a lack of data. Also, because the use of these modes is fundamentally local in nature, integration of biking and walking strategies into regional plans, programs, and budgets remains problematic in many areas. Furthermore, pricing is a fundamental element of any technology strategy and is just beginning to be applied as an explicit demand management strategy. There are few detailed and comprehensive analyses of its impacts.

**Proposed Research** This research study will be threefold:

1. Inventory the full range of demand management strategies that have been implemented, with particular attention to nonmotorized modes and new transportation technologies. Document each strategy's impacts, considering in particular its effects on emissions of GHG and other sustainability metrics. Also, prepare an inventory of the pricing strategies that have been proposed, including congestion pricing, toll pricing of road use, variabilization of motor vehicle costs, parking pricing, paying at the pump, insurance, fuel tax increases to include externality costs, emissions charges, carbon taxes, and other pricing strategies identified by the researchers. Document social, economic, and environmental costs and benefits associated with each pricing strategy and implementation experiences if any, paying particular attention to differences in context and their consequences.
2. Prepare case studies of the implementation of major demand management programs at the state, regional, or local levels and document their effects on mobility, energy use, and environmental quality. Investigate and document the incidence of these impacts by income, race/ethnicity, sex, and geographic area (e.g., central city, and suburbs). Cases should include an explicit focus on modes and strategies that appear to offer the most promise for GHG reduction and improved sustainability.
3. Investigate and document institutional, political, and other factors that appear to have fostered implementation of demand management strategies where they have occurred. Identify key planning practices and legal and regulatory frameworks, as well as the role of leadership, public education, public involvement, etc., in fostering the implementation of demand management strategies. Also, investigate and document factors that have

served as barriers to demand management. Recommend strategies for overcoming barriers, recognizing the variety of local circumstances extant in the United States.

**Cost:** $100,000
**Duration:** 24 months

**3.3. Integrated Transportation/Land use: Environmental Strategies for Sustainability**
Several states and metropolitan regions have implemented programs that combine land use, transportation, and environmental policies into integrated plans and programs. Examples include the state of Oregon's state and regional planning requirements, implemented and refined over the past three decades; the state of Maryland's smart growth program, implemented in 1997; and Atlanta Georgia's Regional Transportation Authority. European Union nations also are beginning to implement similarly integrated programs, as documented in the European Conference of Ministers of Transport final report, *Implementing Sustainable Urban Travel Policies.* These new programs have been in place or under way for several years, long enough that an evaluation of their efficacy is timely. The proposed research would document and evaluate these new initiatives. The evaluation would be designed to help decision makers and practitioners understand what land use policies, planning processes, and combinations of environmental policies and plans and transportation demand management, capital investment, and technological innovation are effective, as well as those that do not work well. It would also be forward looking in examining the planning efforts for incorporating transportation innovations, including new types of vehicles and mobility services, such as smart car sharing and smart paratransit, dynamic ridesharing, and neighborhood vehicles.

**Proposed Research** This study will identify and document integrated transportation and land use environmental technology plans and programs in the United States and other developed countries. Specific measures that are included in the plans and programs will be identified and evaluated, considering their implementation status as well as their social, economic, and environmental performance. Specific land use, transportation, and environmental measures and combinations of measures that have proven effective in various implementation contexts will be identified, along with the processes through which they have been implemented. Measures that have been less successful also will be noted, together with the apparent reasons for lower-than-anticipated performance.

**Cost:** $150,000
**Duration:** 12 months

**3.4. Intelligent Transportation System Technologies for Sustainability**

**Problem Statement** Intelligent transportation system (ITS) technologies offer numerous opportunities for increasing transportation sustainability that have not been fully identified and evaluated. For example, state departments of transportation are using ITS to increase safety and improve traffic flow through better traveler information about road conditions and faster removal of disabled vehicles and other road obstacles. Transit operators are using ITS to manage operations and provide better information to transit users. ITS technology applications are beginning to be extended to provide environmental monitoring—for example, monitoring the transport of hazardous wastes. ITS applications also suggest ways to improve the efficiency of the transportation system; for example, by using smart card applications for time-of-day pricing. Additional research could identify a wider range of potential applications of ITS for reducing environmental impact and increasing sustainability. This research could also identify the longer-term effects of ITS on urban systems and their performance.

**Proposed Research** This research would evaluate ITS technologies' social, economic, and environmental impacts and identify opportunities for using ITS technologies to improve overall sustainability. The research would identify both near- and long-term ITS technologies. For example, ITS technologies could facilitate shared modes of transportation (such as "on-the-fly" car pooling), use stored-value media to permit variable pricing and manage subsidies and other transfer payments, manage parking and provide better traveler information on its availability and location, coordinate transportation information for multiple modes through an automated "mobility management" system, and increase pedestrian and bike safety. ITS technologies also could be applied to identify gross polluters, monitor and enforce speeds, and otherwise regulate transportation systems for safety and environmental performance. The research will identify new strategies for applying ITS technologies to improve sustainability.

**Cost:** $200,000
**Duration:** 12 months

### 4. Reform of Policy Instruments to Encourage Sustainability and Climate-Friendly Policies

**Problem Statement**
Current public policies and the mechanisms that implement them reflect the environmental, political, economic, and technological circumstances of past and current experience. The advent of new system-transforming technologies may necessitate a redesign of many of these policies and policy instruments. New challenges such as global warming also may call for a major overhaul of today's policy instruments in consideration of reducing emissions and fuel consumption. This may include shifting away from petroleum fuels and internal combustion engines, reducing VMT, increasing emphasis on particulate matter and possible climate change threats, and making greater use of market instruments (including travel demand management and VMT-reducing measures). Consider the following examples:

- Road financing is premised on vehicles consuming petroleum fuels roughly in proportion to their use.
- Emissions and fuel economy standards are premised on the use of internal combustion engines and petroleum fuels.
- Vehicle regulation and many types of enforcement of traffic and parking rules have been based on the presumption that the driver of a personal vehicle owns the vehicle.
- Rules limiting jitney services are premised on the ubiquity and effectiveness of conventional bus and rail services.

**Proposed Research**

This project will identify need and opportunities for policy reform and will identify policy instruments that can be used to help government agencies and actors manage and take full advantage of changing technologies, as well as respond effectively to possible new environmental challenges such as global warming. The study will address such questions as

- How and at what levels of government might emissions trading be employed to reduce GHGs?
- What is the role of voluntary programs for emissions reductions?
- What are the implications for public policy of moving toward a vehicle fleet that operate on non-petroleum fuels?
- What policy instruments can be devised that allow for trade-offs between different goals (such as diesel's lower GHG emissions, but higher particulate emissions)?
- What are the regulatory issues associated with a growth in car sharing?
- Would new forms of "smart paratransit" suggest a rethinking of regulations on transit, taxis, and other forms of transportation?
- What policies and programs are needed for pricing and other demand management strategies to be applied most effectively?

The project will include a conference based on results from a field survey of both transportation and environmental professionals. The resulting report will include a discussion of best practices in the field of transportation and sustainability. The report will present 3 to 5 (or more depending on developments) best practices and a "how-to" guide for implementation purposes.

**Cost:** $175,000
**Duration:** 12–18 months

### 5. INSTITUTIONAL ARRANGEMENTS AND PLANNING PROCESSES FOR SUSTAINABILITY

**Problem Statement**
Decision-making institutions must be capable of meeting the challenges posed by global climate change and sustainability issues. This requires capacity building at both the policy and technical levels of transportation agencies, planning organizations, and state and local governments. It also requires exploration of the barriers to effective coordination between transportation decisions and land development. Research is needed to identify the institutional arrangements and policy structures that have the capacity, authority, and public support needed to effectively carry out sustainable transportation planning and project development.

**Proposed Research**

*Part I: Institutional Arrangements and Planning Processes for Sustainable Transportation*
This research would identify institutional arrangements and planning processes that effectively support integrated, performance-based planning and decision making. Specific topics to be addressed include organizational arrangements and assignments of responsibility, methods, and processes for

1. Better integrating transportation, land use, and environmental planning and programming, and for considering both capital and noncapital strategies for mobility improvement;
2. Communicating the results of sophisticated technical analyses and performance comparisons to decision makers and the public;
3. Incorporating customer needs, preferences, and viewpoints into the decision-making process;
4. Better coordinating land use and environmental decision making across disparate agencies and programs; and
5. Dispute resolution.

The research will focus as much or more on institutions as on techniques. It will also examine the contribution of institutional barriers to the current lack of integration of planning functions and suggest structural changes that can eliminate the most significant barriers.

**Cost:** $150,000
**Duration:** 18 months

*Part II: Transportation Finance*
Transportation decision making is strongly influenced by the sources and amounts of funding available for various activities and for the mandates and limitations imposed on the use of funds. The implementation of sustainable transportation strategies may alter existing petroleum-based revenue streams and could also provide new revenue sources. This project will evaluate how various transportation strategies being proposed for GHG reduction and sustainable development are likely to affect transportation revenue streams. For example, petroleum-based taxes will decline as electric and other alternative-fueled vehicles penetrate the market; strategies that dampen travel growth and increase vehicle fuel efficiency may reduce per capita revenues based on fuel consumption. Pricing strategies, on the other hand, would generate new revenues, and how the revenues are directed will have implications for mobility as well as for environmental and economic performance. The project also will identify alternate strategies for providing adequate funding for a sustainable transportation future. For each strategy, efficiency, equity, and political acceptability will be evaluated.

**Cost:** $150,000
**Duration:** 18 months

### 6. FORECASTING AND ANALYTIC TOOLS TO SUPPORT STATE AND LOCAL GLOBAL WARMING STUDIES

### Problem Statement
Transportation organizations in the United States have not had the opportunity to study their current and planned transportation systems, including vehicles and fuels, to examine the degree to which they contribute to climate change. Although the issue is on the minds of many officials, few modeling tools have been made available for climate change analysis. A modeling structure does exist for transportation planning and air quality analysis. It is widely used and supports planning for highway and transit systems and for air quality conformity analysis. Models also

are widely used for traffic operations analyses. These models could be enhanced to produce estimates of GHG emissions.

**Proposed Research**
This project will review the most commonly used models and identify those that could be enhanced in a cost-effective manner to produce information about GHGs. The core transportation models would not be entirely rewritten, but additional routines might be added or, alternatively, post-processors could be provided to calculate GHG emissions from the vehicles moving on the transportation systems. The models will also be reviewed and recommendations will be made on other modifications to the software to more broadly include benchmarks and sustainability measures (to be addressed in a separate effort.)

These models can then be made available to states and metropolitan planning organizations that want to undertake studies to help understand global climate change consequences of existing transportation systems and proposed changes to them.

**Cost:** $150,000
**Duration:** 12 months

**7. BENCHMARKING TRANSPORTATION FOR SUSTAINABILITY**
Benchmarking is “the process of identifying, understanding, and adapting outstanding practices from organizations anywhere in the world to help your organization improve its performance."

**Problem Statement**
In the realm of transportation system performance, one of the greatest demands from both within and outside the transportation planning community is for assessment of the sustainability of alternative transportation and land use plans. There is a need for methods and tools that can be used to test alternative visions and public policies against the ability of a metropolitan area or community to maintain its systems over time. Research regarding the impacts of transportation policy and investments on environmental protection and enhancement, energy consumption, land consumption, economic health, and affordability must be translated into tools available for use at the front lines of transportation decision making. The need for this particular facet of performance measurement is compounded by the fact that the United States will have to accommodate the activities of tens of millions of additional residents in the coming years. Metropolitan areas such as Atlanta, Georgia, and Dallas–Fort Worth, Texas, continue to absorb population growth in excess of 10,000 residents per month. These rapidly growing areas have a tremendous need for tools that can be used to assess the long-term sustainability of current practices.

**Proposed Research**
Research is necessary to identify a range of potential benchmarks that will provide transportation planners with the indicators they need to evaluate progress towards new policy goals. The indicators should also enable comparison between jurisdictions. The research would

- Review the current state of the practice in benchmarking techniques and approaches, both in the United States and abroad, particularly in relation to transportation and sustainability.

- Identify common measures (both existing and needed) and indicators of sustainability for use by all levels of government.
- Identify the data needs necessary to support the use of such indicators.
- Initiate a process by which selected urban areas and states would compare their development and use of benchmarks.

**Cost:** $600,000
**Duration:** 24 months

### 8. TRAVELER ATTITUDES AND BEHAVIOR TOWARD SUSTAINABLE TRANSPORTATION

**Problem Statement**
Unlike most other countries, travelers in the United States rely on motor vehicles for virtually all local and regional travel. Moreover, the vehicle population of the United States tends to be rather homogeneous relative to other countries. Very few small vehicles are used and almost all vehicles operate on gasoline and diesel fuel. With the proliferation of vehicles (more than one per licensed driver), the availability of low-cost wireless and information technologies, and the introduction of new fuels and propulsion technologies, the opportunities arise to better serve travelers. Traveler desires can be met at lower cost, with higher quality service, and/or lower environmental impact. Currently in the United States, most travelers do not reflect on their choice of mode with the advent of new technologies and a growing awareness of the health and livability cost associated with high dependence on car travel; therefore, it is time to better understand traveler behavior. However, little information currently exists about the public's willingness to accept likely attributes of these new transportation technologies (such as home recharging of electric vehicles, the safety aspects of new fuels, or the use of smaller vehicles in various settings.) Research is needed on traveler attitudes and behavior in the context of the broader set of transportation choices becoming available to consumers. Research also is needed on ways to provide the public with information about travel choices and to educate them about the consequences of their choices.

**Proposed Research**
The proposed research will investigate traveler attitudes and behavior to better understand the conditions and circumstances under which travelers would make more sustainable transportation choices; that is, choose to walk or bike, use car sharing and other "smart" mobility services (e.g., dynamic ride sharing), buy and use environmentally beneficial vehicles and fuels (fuel cell vehicles, small battery electric vehicles), or reduce travel through telecommunications substitutes. The research also will examine ways in which new transportation technologies could be introduced to the marketplace, including the identification of possible new market segments for innovative transportation options. Roles for and effects of marketing and public education, especially with regard to "new" vehicle attributes and transport services unfamiliar to consumers, will be examined. Finally, the possibility that new transportation choices could lead to significantly different activity patterns and work styles will be considered in assessing the implications for travel, vehicle choice, energy use, and the environment.

**Cost:** $200,000
**Duration:** 24 months

## 9. Sustainability Analysis Pilot Program for State and Local Governments

### Problem Statement

GHG emissions and other sustainability issues are of concern to federal, state, and local governments. Policy debates increasingly involve the question, What are you doing about the possibility of global warming? Or more specifically, transportation officials are asked; Are your investments sustainable? Although the federal government has been involved in global warming discussions for many years, very few opportunities have existed for state and local transportation officials to evaluate their infrastructure and the vehicles on them to consider the sustainability implications of current policies and practices and the potential implications of project and program proposals. There is an urgent need for state and local officials to better understand the sustainability characteristics of their systems if they are to be informed participants in the discussions/debates that will lead to the development of national policies. It would be extremely costly if all state and local governments were to undertake such analyses, especially since at the present time there are no well-established approaches for such studies. A pilot program can serve to develop methods and procedures and to establish the feasibility and desirability of sustainability analysis.

### Proposed Research

This project will establish a grant program to allow three states and three metropolitan planning organizations (MPOs) to undertake pilot sustainability research projects to permit them to understand the degree to which their current and proposed transportation systems are sustainable under criteria they will establish. Computer software will be provided to allow the selected recipients to undertake a GHG emissions analysis of their existing systems. The projects will then look at the various policies or policy packages that will be necessary to allow them to meet their sustainability criteria.

**Cost:** $600,000 ($100,000 each to three state departments of transportation and three MPOs)
**Duration:** 24 months

## 10. Freight Transportation and Sustainability

### Problem Statement

Sustainability, in the broader view, is comprised of economic, environmental, and social components. Economic stability and growth is partially dependent on the successful movement of freight. Truck usage alone has grown and now accounts for more than 90% of all shipments. Also, since 1970 truck travel has more than tripled, with the number of heavy combination trucks nearly quadrupling. Combined with the movement of people, freight movement can have a profound impact on achieving sustainability, including climate change. There is a need for a national, state, and local information system developed for state and MPO planners to facilitate the introduction and evaluation of innovative major infrastructure improvements and investments to promote intermodal coordination and to enhance the efficiency of goods movement. The result should be an increase in economic efficiency and performance while reducing energy use as well as GHGs and conventional emissions leading to sustainability.

**Proposed Research**
A better understanding of the future movement of freight is needed to influence a sustainable approach to freight transport. To achieve an understanding of freight movement, research is needed that will identify the sustainability characteristics of freight transport. Furthermore, there is a need for a local, state, and national information system developed to facilitate the introduction and evaluation of innovative infrastructure improvements and investments to promote intermodal coordination and to enhance the efficiency of freight movement leading to sustainability. Sustainable alternatives will need to consider energy efficiency that will likely require novel and innovative research initiatives for freight systems and major infrastructure investments (i.e., maglev) by government and the transport industry.

**Cost:** $175,000
**Duration:** 12 months

### 11. ECOSYSTEM IMPACTS: INTEGRATED PLANNING STRATEGIES AND ASSESSMENT METHODS

**Problem Statement**
A 4-million-mile public road network carrying 230 million vehicles covers approximately 1% of the United States—equal to the size of South Carolina. A recent article published in *Conservation Biology* presenting the first calculation of the ecological effects of this road system suggests that roughly one-fifth of the total U.S. land surface is directly affected. The current road network was essentially built prior to the first Earth Day in 1970, long before the explosion in environmental knowledge represented by modern ecology. The Transportation Research Board report, *Toward a Sustainable Transportation Future,* identifies ecosystem impacts as a key sustainability issue.

Landscape ecology is a rapidly developing body of knowledge and research that represents a relatively new, highly useful, and far-reaching dimension for consideration in transportation planning and activity. Landscape ecology (including the related areas of conservation biology and watershed science) provides principles and models that directly address issues such as habitat fragmentation; arrangements of green patches; wildlife corridors for foraging, dispersal, and migration; and groundwater and surface-water flow paths, all of which can be related to transportation networks. Integrating transportation systems with these principles, processes, and models is a key collaborative opportunity for engineers, ecologists, and planners. The results of such collaboration should have notable application in transportation planning, evaluation of transportation projects, and overall environmental stewardship. They also should establish an important approach for addressing sustainability issues.

**Proposed Research**
The recommended research builds on strong foundations in transportation research in such areas as hydrology, sediment flow, roadside vegetation management, roadkill, traffic flows, and pollutant emissions, all factors that are critical to environmental sustainability. The research will develop a methodology to integrate transportation systems planning and ecosystems planning. At the planning and ecosystem level opportunities exist to approach problems on a broad basis, where the greatest number of options for solution exist. For example, wildlife movements over large habitat areas can be studied to determine the most cost-effective ways of avoiding habitat fragmentation. The research will also identify ways transportation agencies can integrate

ecosystem considerations into planning design, construction, and management. This integrated approach should identify opportunities to develop more ecosystem-friendly new projects, as well as identify appropriate maintenance and reconstruction policies and practices, including opportunities to mitigate situations where existing projects fragment habitat, impede migration, or obstruct fish spawning routes. Lastly, the project will identify ways to better integrate wildlife and plant resource considerations in the National Environmental Policy Act of 1969 (NEPA) process. Ecosystem approaches should help develop more meaningful treatment of species of flora and fauna than the often-seen project area-limited-species list approach observed in many Environmental Impact Statements. Ecosystem consideration should facilitate the dialogue between transportation agency and resource agency staff and create opportunities to break away from “compliance” debates toward positive discussions on how to create win–win situations for transportation and wildlife, resulting in a more sustainable transportation system.

**Cost:** $200,000
**Duration:** 24 months

### 12. Cumulative, Areawide, and Indirect Impacts of Transportation

**Problem Statement**
Most roads, railroads, ports, airports, and transportation support infrastructure were built prior to mainstream environmental analysis and assessment. The numbers of vehicles, boats, and miles traveled on these facilities continue to increase. One result is a variety of adverse impacts on the human and natural environments: air pollution, traffic noise, water pollution, congestion, neighborhood disruption, habitat fragmentation, invasive species, disposal and recycling concerns, and climate change. Although impact assessment has traditionally been project-related, there is growing understanding that cumulative, areawide, and indirect impacts and their interactions are highly significant and are an indicator of overall sustainability. Better methods for addressing cumulative and areawide impacts must be integrated into transportation planning and evaluation practices if we are to effectively increase the sustainability of the transportation system. Planning and design approaches are needed that would protect and enhance human and natural environments, as well as reestablish healthy conditions in areas that currently are adversely affected by transportation, if we are to achieve a sustainable transportation system.

**Proposed Research**
This project will identify best practices for addressing the cumulative and areawide impacts of transportation including, when possible, the quantification of these impacts. The research also will examine and recommend ways to go beyond the current limited focus of individual transportation projects so that consideration is given to corridor, regional, and systems effects of transportation. The identified practices should allow project proponents to better understand and quantify the cumulative effects of their actions on sustainability. Planning and project development approaches will be recommended that emphasize environmental stewardship and incorporate environmental considerations into project design, rather than focus on simply mitigation. The results could also have utility applied in the NEPA environmental assessment process.

**Cost:** $300,000

**Duration:** 24 months

**Collaborative Research Needs Statements**

**13. ANALYZING THE SUSTAINABILITY OF VARIOUS ALTERNATIVE FUELS AND ADVANCED TECHNOLOGY VEHICLES IN SELECTED NICHE VEHICLE MARKETS**

For full text, see Section 2 under Energy and Alternative Fuels

**14. POTENTIAL TRAVEL RESPONSES TO ALTERNATIVE HIGHWAY PRICING AND FINANCING SYSTEMS AND THE IMPACT ON FUEL CONSUMPTION AND GREENHOUSE GAS EMISSIONS**

For full text, see Section 3 under Energy and Alternative Fuels.

**15. FUEL ECONOMY AND GLOBAL WARMING: UNDERSTANDING CONSUMER BEHAVIOR AND THE INCREASING AWARENESS OF LINK THE BETWEEN FUEL CONSUMPTION AND GLOBAL WARMING**

For full text, see Section 7 under Energy and Alternative Fuels

**16 PREPARE A COMPENDIUM OF SUSTAINABLE DESIGN IDEAS FOR USE BY A WIDE RANGE OF TRANSPORTATION SEGMENTS**

For full text, see Section 5 under Waste Management and Environmental Management: Recycling, Waste Reduction, Pollution Prevention, Brownfields

**17. CREATE A METHODOLOGY TO INTEGRATE SUSTAINABLE DESIGN CONCEPTS INTO TRANSPORTATION PROJECTS AND INFRASTRUCTURE**

For full text, see Section 6 under Waste Management and Environmental Management: Recycling, Waste Reduction, Pollution Prevention, Brownfields.

# Transportation, Human Health, and Physical Activity

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RESOURCE PAPER

# Transportation Impacts on Human Health, Especially Physical Activity

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Transportation's impact goes beyond the primary purpose of moving people and goods, as illustrated by its recognized effects on the environment and emerging recognition of its effects on public health. For the first time, this group considered the wide variety of public health issues that are empirically or logically linked with transportation infrastructure and travel choices. The group was strongly motivated to demonstrate the relevance of public health issues for transportation research and practice. Health is a major societal value, and finding common ground between health and transportation could significantly advance the interests of both sectors.

Nonmotorized transportation (NMT) is one component of physical activity that also includes leisure and work-related physical activity. The most common forms of NMT are walking and cycling, but other forms include skating and wheelchair use. NMT was a particular focus of the working group because

- Physically inactive lifestyles are a leading cause of death and disability, accounting for at least 200,000 deaths in the United States each year, second only to tobacco use.
- Physical inactivity is the most prevalent chronic disease risk factor, with 60% of adults not meeting physical activity recommendations.
- Walking and cycling are two of the most common physical activities for adults; they can be done for transportation and they make use of transportation infrastructure.

The working group identified a small number of issues that were believed to be central to creating a strong and lasting partnership between public health and transportation and that would support the proposed research agenda.

1. NMT is a commonly used and recognized mode of travel, but the systems and resources needing for monitoring and managing these modes are inadequate. Increasing NMT can have benefits for transportation and health.
2. It is essential to identify the links between transportation issues and a range of health outcomes; health behaviors, physical health, mental and social health, health care costs, and others.
3. Collection of data on NMT should be integrated into the regular transportation data sources so that health issues can become institutionalized into transportation planning.
4. There is a high priority on conducting studies that can guide transportation decisions that will be favorable for health outcomes.

5. Because the research priorities focus on the intersection of health and transportation, it is assumed the studies need to be conducted by multidisciplinary teams that include transportation and public health professionals.

Several crosscutting issues were identified that are generally considered to be important in health research and that apply generally to research needs statements.

- Whenever possible, data should guide decisions. Thus, adequate measures of NMT and other health topics need to become part of the transportation data collection systems.
- In this new area of research on transportation and public health, it is anticipated that many new measurement methods will need to be developed and evaluated.
- There are parallels between environmental justice concerns and disparities in health. In both cases, people of color and lower socioeconomic status groups are disadvantaged. For many research topics, the studies need to focus on the subgroups in most need or ensure that the full diversity of the population is addressed.
- Although some specific health issues are identified, it is also important to assess or otherwise consider global indicators of health and well being such as quality of life and social capital to ensure that benefits in one health outcome are not offset by decrements in other health outcomes.

### Consequences of Physical Inactivity

Only recently have we come to understand that physically inactive lifestyles are one of the major public health problems of our time. The epidemiological evidence linking physical inactivity with numerous health problems emerged mainly in the 1970s and 1980s. At this time, physical inactivity is a well-documented risk factor for the chronic diseases that kill most Americans, including coronary heart disease, stroke, some cancers, diabetes, and depression (*1*). Inactive lifestyles are responsible for approximately 200,000 deaths in the United States each year, second only to tobacco, which kills approximately 400,000 (*1, 2*). Leading a sedentary lifestyle is about as dangerous to one's health as smoking a pack of cigarettes each day, but whereas less than 20% of adults are heavy smokers, approximately 60% do not meet physical activity recommendations (*3*). It is estimated that physical inactivity costs more than $77 billion per year in direct medical costs alone and is believed to contribute to the current epidemic of obesity (*4*). A nationally representative sample shows that one in five U.S. adults are obese (body mass index or BMI > 30.0 kg/m$^2$) and more than half (56%) of the U.S. adult population is overweight (BMI > 25.0) (*5*). These are increases of greater than 60% in the past decade alone, with similar increases common among youth (*6*). All of these factors are leading public health officials at federal and state levels to look closely at the causes of physically inactive lifestyles and to search for solutions that can improve health and save money.

Health and transportation professionals have examined physical activity from different perspectives. Although health is affected by total physical activity, virtually all of the research to date has been on leisure, physical activity, and walking, which is the most common form of adult physical activity (*1*). Brisk walking has been identified as protective of physical health, particularly if done consistently (*7*), independent of the benefits of more vigorous activity (i.e., activities that are traditionally considered "exercise," such as running, swimming, etc.) (*8*). Current public health recommendations emphasize the need to accumulate 30 min of physical activity daily of at least moderate intensity, including walking and cycling (*1, 9*).

By contrast, transportation and urban planning researchers have been interested almost exclusively in walking and cycling for utilitarian purposes. Until recently, health and transportation researchers were unaware of each other's somewhat complementary approaches. However, as health researchers have become more interested in exploring the environmental correlates of physical activity (*10*), they have encountered studies on NMT. Transportation research already has made an impact on the health field, as indicated by the fact that *Healthy People 2010* has targeted a more than 50% increase in walking trips made by adults for trips of less than 1 mile (*3*). The combination of transportation and health perspectives in research studies may help us understand some of the reasons why the majority of U.S. adults lead physically inactive lifestyles.

It is necessary to improve our understanding of the factors that influence individuals' frequency and duration of walking and other physical activity behaviors to provide an empirical basis for public health action. Few studies have examined correlates of "walking for exercise" (*11, 12*). The combination of psychosocial and environmental policy variables is expected to best explain physical activity (*13–16*). However, physical activity research to date is limited to studying primarily psychosocial correlations (*16*), although recent studies have examined physical environmental variables (*17–19*). By contrast, transportation and urban planning research has a strong tradition of examining environmental and policy correlations of transportation behaviors.

## Relevance of Transportation Research Agenda to Physical Inactivity

Historically, transportation research has been focused largely on the study of vehicular travel and factors such as travel cost, demographics, and other aspects of convenience and access (e.g., transit and roadway level of service and parking availability). More recently, however, transportation research has become concerned with built-environmental determinants of nonmotorized or "human powered" modes of travel, driven largely by the need to reduce automobile-generated pollution.

Researchers in transportation, urban design, and city planning have long understood that neighborhood design and the way land is developed and used affects travel behavior (*20*). Two fundamental concepts of urban form that impact travel choice in general, and nonmotorized travel in particular, are the proximity (land use density and mix) and connectivity (route directness) between complementary activities (e.g., work, shop, and play). Proximity relates to the distance between trip origins and destinations. Proximity is a function of land use, density, and mix, while connectivity characterizes the ease of moving between origins (e.g., households) and destinations (e.g., stores and employment) within the existing street and sidewalk or pathway structure (*20*).

Although the concepts of proximity and connectivity are familiar to transportation research professionals, these factors are pertinent to understanding an individual's overall level of physical activity. For instance, approximately 83% of all "trips" (each instance of moving from a point of origin to a destination) are short, for nonwork purposes, and occur relatively close to home (*21*). The majority of nonwork trips are within walking or cycling distance and are therefore of interest to the physical activity, air quality, and transportation planning fields.

Although there is a long history of transportation and land use planning based on health, safety, and public welfare considerations, contemporary concerns about physical activity raise new issues of relevance to transportation researchers and practitioners. Plainly stated, the hypothesis is that the land uses, transportation policy, and infrastructure that have been dominant since World War II favor automobile use so heavily that most people have little or no ability to walk or cycle for transportation. This appears to be an historic and dramatic shift away from millennia of experience in which walking was the major form of transport. Current reliance on single-occupant vehicle use, along with other factors contributing to more sedentary lifestyles (e.g., application of technology to work and entertainment), has engineered physical activity for nonexercise purposes out of many American lives. Most of the evidence for the hypothesis can be found in the research literature on NMT.

Related studies were identified from the Transportation and Urban Planning Research literature by searching the TRANSPORT bibliographic database using terms including “walk,” “walking,” and “cycling.” Titles and abstracts were screened to identify research examining environmental factors related to walking or cycling that contained some measurement of individuals’ walking and cycling behavior as an outcome variable. One common research methodology compared differences in walking and cycling rates between residents of neighborhoods that differed in environmental characteristics. Table 1 provides comparative estimates of walking and cycling rate differences between neighborhoods purported to be more walkable (e.g., higher population density, greater mixed land use, higher connectivity) versus less walkable (e.g., low density, mostly residential land use, low connectivity). When not provided in the published article or report, absolute weekly walk or bike trip estimates were derived from the percentage of trips made by walking or cycling, based on an assumed 30 trips weekly across transport modes (*21*).

In the United States, the frequency of walking trips per week in comparison with other travel modes (e.g., automobile) was low, regardless of neighborhood environment (*21*). However, the number of estimated weekly walking or biking trips reported by residents of high-walkable neighborhoods was consistently higher than for low-walkable neighborhood residents. Summing across trip purpose for studies providing walk or cycling rates by trip purpose (*22, 23, 26, 27*) and using an unweighted average across all studies presented in Table 1, high-walkable neighborhood residents reported approximately two times more walking trips per week than low-walkable neighborhood residents (3.1 versus 1.4 trips). Magnitude differences between high- and low-walkable neighborhoods (high-low) ranged from –0.1 to 5.7 walk trips and were partially dependent on trip purpose. Walking to work and for errands appeared more likely in high than low-walkable neighborhoods (*22, 23, 26, 27*). Handy’s findings (*26, 27*) suggested that these utilitarian trips (e.g., shopping) were the source of overall differences in walking trips between high- and low-walkable neighborhoods, because walking for exercise did not differ between high- and low-walkable neighborhoods (*26–28*).

Other transportation and urban planning studies have used correlational designs to examine the magnitude of built-environment associations with NMT *beyond* travel choice explained by sociodemographic variables (Table 2). Neighborhood environment characteristics were related to walking and cycling for transport in virtually all of the studies reviewed here. Population density was among the most consistent positive correlation of walking trips (*21, 23, 31*). In the 1995 Nationwide Personal Transportation Survey, travel by walking and cycling was approximately five times higher in the highest versus lowest density areas (*21*). Frank and Pivo (*32*) found that population and employment density were independent positive correlates of walking rates for commuting and shopping, after accounting for such factors as vehicle ownership, resident age, and driver’s license status. Land use mix, especially the close proximity of shopping, work, and other nonresidential land use to housing, appeared related to greater walking and cycling among residents (*33, 34*). Commuting to work by walking or cycling was higher in areas of more mixed land use (*32*) and where commercial facilities existed nearby (<300 feet, approximately 0.1 km) (*35*). Limited evidence suggested that better walking and cycling infrastructure (e.g., sidewalks and bicycle paths) was related to more walking and cycling trips (*29*). When sidewalk continuity was used as one of the criteria for determining neighborhood walkability, high-walkable neighborhoods showed higher rates of walking and cycling (*31*). In one study, improved pedestrian facilities were related to higher pedestrian rates at commercial centers even when other environmental characteristics, including density and land use mix, were constant (*36*). Although not specifically examining walking and biking rates in their study, Cervero and Kockelman (*37*) found that better pedestrian infrastructure, including sidewalks and street lighting, was related to greater nonautomobile travel, particularly for nonwork trips originating from home. Walking and cycling infrastructure research has already begun in the health and physical activity empirical literatures (*17, 38*).

In summary, studies employing neighborhood comparative and correlational designs demonstrated consistent associations of neighborhood environmental factors with walking and cycling for transport. The strength of associations varied, but was usually substantial. From a physical activity and health perspective, the estimated mean difference between high- and low-walkable neighborhoods of approximately 1 to 2 walk trips per week translates into 1 to 2 km or approximately 15 to 30 min more walking per week for each resident of high-walkable neighborhoods. For a 150-lb person over 1 year this translates into an extra energy expenditure of approximately 3,000 to 6,000 kcal, which could result in weight loss of 0.85 to 1.75 lb. Such moderate-intensity physical activity, undertaken by a large proportion of the population over time, could have a significant public health impact. Indeed, recent evidence suggests that walking or cycling for transport to work is associated with lower body weight and lesser weight gain over time, independent of the effects on body weight of more vigorous physical activity (*7*). Especially in the current context of no apparent increase in adult physical activity during the 1990s (*3*), the potential to enhance physical activity in entire communities by 15 to 30 min per week should be taken seriously by public health officials.

## Physical Activity Studies Can Inform Transportation Research

In the physical activity and public health literature, a few studies can be identified that have implications for the transportation field. For example, preschool children were more physically active when there were places nearby, such as parks, where they could play (*39, 40*). Ensuring that play spaces are within walking distance to homes could be expected to both increase children's physical activity and reduce the necessity for driving children to a recreation facility. There is growing evidence that elementary and middle school children are dependent on parental transportation for their physical activity (*41, 42*). The need for parents to transport children for physical activity is likely a function of suburban land use patterns and a lack of planning for youth mobility, but this remains to be proven.

The availability of recreational facilities near homes appears to be related to adult physical activity. The self-reported presence of convenient physical activity facilities has been associated with exercise by adults (*43*), predicted increases in walking (*12*), and predicted adoption of vigorous exercise for men but not women (*44*). An objective measure of the density of exercise facilities around participants' homes was related to exercise levels, even after adjustment for age, sex, and education level (*45*). These studies imply that planning exercise facilities near homes can promote leisure-time physical activity. It can be hypothesized that placing the facilities within walking or cycling distance of homes could reduce driving to recreational destinations. Indeed, preference studies suggest that individuals are more likely to trade-off larger individual lot sizes for common recreational green spaces relative to other potential benefits of pedestrian proximity trade-offs (*46*).

## SYNERGY OF TRANSPORTATION AND PHYSICAL ACTIVITY RESEARCH NEEDS AND FUTURE DIRECTIONS

Although the issue of physical activity and public health seems far from the concerns of transportation professionals, this review shows that land use, the transportation infrastructure, physical activity, and public health are actually closely interrelated. As these findings become more widely known, transportation policy will appear more prominently on the public health agenda. It is unlikely that transportation and land use decisions in the past have been made with consideration of effects on physical activity. Now that transportation decisions are shown to affect physical activity and health, the transportation field needs to put physical activity on its agenda for both practice and research. The transportation professions need to be involved in coalitions seeking to improve public health by increasing physical activity (*10*).

Transportation experts have identified nonmotorized travel usage and user characteristic research as high priority and have identified many gaps in existing empirical literature on walking and cycling for transport (*47*). The transportation literature leaves unanswered many questions that are important for physical activity and public health. Multidisciplinary teams that combine the expertise and perspective of relevant professionals can best undertake research on topics that converge on transportation, physical activity, and public health. We suggest research topics that may be considered priorities for both the transportation and public health fields.

1. Because travel choice is often measured categorically (e.g., walking trip versus auto trip), the duration and intensity of walking and cycling are unknown. Whereas walking trips for utilitarian purposes are generally short, physical activity benefits can be incurred with multiple short bouts of activity (*9*). Most transport studies also assess only 1 or 2 days of travel; therefore, there is limited generalizability to habitual physical activity. Reliance on unvalidated self-report measures of transport behavior introduces further error. Improvements in measurement of nonmotorized travel behavior as well as inclusion of valid physical activity measures in transportation studies could both improve the quality of transportation research and its contribution to public health knowledge.
2. The transportation and urban planning studies showed that community design variables of mixed use, density, and connectivity were consistently related to NMT. Research to more precisely define these variables, as well as exploration of other hypothesized environmental correlates of NMT and physical activity (e.g., walking and cycling infrastructure), is needed to define optimal land use patterns for different contexts (e.g., urban, suburban, small town) that define "walkability." There is a particular need to study infrastructure and policies that specifically serve pedestrians and cyclists. Variables of particular interest include presence, maintenance, and buffering of sidewalks; crosswalks, pedestrian signals, and mid-street islands on busy streets; pedestrian over- and underpasses; and presence of bicycle lanes and trails (*17, 38*).
3. The attempt to identify unique contributions of specific neighborhood environmental characteristics is hampered by the high interrelatedness of land use variables. For example, neighborhoods with high density also tend to have greater mixed use and connectivity. This spatial multicollinearity makes it difficult to determine the independent contribution of urban

form variables on travel mode choice (*23*). This can be overcome by examining locations and neighborhoods that differ on only one environmental walkability factor (*36*). Strategies to isolate the effects of specific land use and transportation variables may require larger studies than those conducted to date.

4. The aesthetics, comfort, and safety of pedestrian and cycling environments are likely to influence physical activity for transportation and leisure. For example, tree canopy, topography (e.g., street inclines, natural barriers such as waterways), variety in streetscapes, building setbacks, traffic volume and speed, traffic calming measures, and the ability to be seen from buildings have been discussed but not studied.

5. The impact of public transit facilities and policies as well as transit-oriented development patterns needs to be investigated on NMT and overall physical activity.

6. To date, transportation and urban planning research has been conducted in only a small number of U.S. cities (e.g., the San Francisco Bay area; Seattle, Washington; and Portland, Oregon). Rural areas remain largely unstudied, with some exceptions (*17*); therefore, studies of correlates of NMT and physical activity in a greater variety of geographic settings are needed.

7. One limitation to examining environmental correlates of physical activity that will require innovative research designs is the inability to randomly assign residents to different neighborhoods. Quasi-experimental designs do not prevent the possible introduction of biases and values affecting the choice an individual makes about where to live. In attempts to isolate environmental influences, research designs would benefit from keeping the same individuals within an environment that is subsequently modified, with the assumption that individual attitudes and values about travel and physical activity would remain stable. Pre-post designs to examine effects of environmental changes are common in transportation and urban planning research (*47*). Strategies have been proposed for neighborhood retrofitting that would enhance factors purported to increase walking [e.g., increasing connectivity (*48, 49*)]. Future research needs to evaluate the impact of these environment modifications on actual walking and cycling among residents before and after retrofitting.

8. Some recreational physical activity could be motivated by people's inability to obtain physical activity for utilitarian purposes. It is possible that driving trips to recreational facilities could be reduced by:

- Changes in land use that make it easy to commute or shop by walking or cycling,
- Locating more recreational facilities within walking or cycling distances of homes or workplaces, or
- Designing recreational facilities, like rail-trails or greenways, that can be used for both recreational and utilitarian purposes.

Hypotheses such as these need to be tested.

9. Neighborhood and individual sociodemographic characteristics have rarely been examined or reported in transportation research, but these can be highly influential factors in NMT behavior (*18, 36, 50*). The possibility that land use has differential effects on people with varying characteristics (e.g., ethnicity, socioeconomic status, disability status) seldom has been explored; therefore, increasing the diversity of the neighborhoods and samples investigated should be a high priority.

10. There are likely to be significant age differences in the environmental and policy factors that affect NMT and physical activity, but these issues have not been studied in the transportation field. A high priority should be placed on ensuring that transportation research is relevant for all sectors of American society.

- An improved understanding of children's transportation needs could lead to reductions in the number of trips to needed drive children. Identifying factors that affect walking and cycling to school could inform environmental and policy changes.
- Environmental factors that have a particular influence on older adults' physical activity and the perceived safety of NMT need to be identified.
- Environmental factors that have a particular influence on NMT and physical activity among people with physical disabilities need to be identified.

11. Data at different levels of aggregation (e.g., individual psychosocial variables related to physical activity and neighborhood environmental characteristics) need to be collected to fully understand the correlates of NMT and physical activity. It may be beneficial to examine interactions of environmental and psychosocial variables, in addition to the interaction between environmental and sociodemographic variables known to influence physical activity. Figure 1, although not comprehensive, proposes a model for next possible steps in the evaluation of environmental and psychosocial variables involved with physical activity. Future consideration of these factors will require more sophisticated multilevel modeling and analytic methods (e.g., hierarchical linear models) that have begun to be incorporated into transportation (*51*) and physical activity research (Masse et al., unpublished work).

12. Although it is clearly valuable to investigate objective measures of physical environments using geographic information systems, it is also useful to collect measures of perceived neighborhood environment. Perceived and objective environmental measures may have independent, synergistic, or shared associations with walking and cycling, and it may be most useful to include both objective and subjective modes of environmental assessment. Perceptions of neighborhood may be especially important in evaluating the factors related to residential choice, as this could better inform the nature and directionality of the relation between neighborhood environment and walking or cycling.

13. Although it is possible to alter laws and policies governing new developments to make them more walkable, there will be many challenges. It will be much more difficult to develop and implement methods of improving the walkability of the vast tracts of low-walkable suburbs that house millions of people. A high priority should be placed on identifying variables that are related to the walkability of suburban neighborhoods and strategies to improve walkability that could gain political acceptance.

14. As a consensus emerges about transportation policies and practices that can increase NMT and physical activity, the economic impact of the recommended policies and practices needs to be documented. Such evidence is needed to inform decision making.

15. Because NMT is relatively rare and physical activity levels are generally low in the United States, changes in transportation policies and practice are needed. Because such changes will take years and involve many decision makers, evaluation research is needed to improve understanding of transportation decision-making processes at multiple levels of government and in the private sector.

## CONCLUSIONS

The design of communities and transportation systems is strongly related to NMT behavior; however, the effect of environmental policy variables on total physical activity is not clear. Because large proportions of people in the United States live in the sprawling and exclusively residential environments associated with low levels of walking for transport, land use and transportation policies may already be having a substantial, although generally undocumented, impact on public health. Professionals from numerous fields are concerned that we have built our communities so that it is difficult, and in many cases dangerous, to walk or bike, and have thus "engineered" physical activity out of our daily lives. There is a public health imperative to evaluate environmental and policy variables and their associations with NMT, recreational physical activity, and total physical activity. The results of such studies can inform efforts to alter the environments in which people live their daily lives so as to promote population shifts in physical activity and improve transportation systems. Conducting and applying research on environmental correlates of NMT and physical activity will require collaboration among researchers from a wide range of professions.

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**TABLE 1 Estimated Average Walking Trips Per Week Among Residents of High-Walkable Versus Low-Walkable Neighborhoods**

| Ref. No. | Geographic Location | High-Walkable Neighborhoods | | | | Low-Walkable Neighborhoods | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Non-Work | | Work | Total | Non-Work | | Work | Total |
| | | Errand | Exercise | | | Errand | Exercise | | |
| 22 | San Francisco Bay Area and Los Angeles | — | | 0.9 | — | — | | 0.3 | — |
| 23 | San Francisco Bay Area | 1.4 | | 0.7 | — | 0.4 | | 0.1 | — |
| 24 | Palm Beach County, Fla. | — | | — | 0.2 | — | | — | 0.3 |
| 25 | San Francisco Bay Area | 2.8 | | 0.4 | 3.6 | 2.0 | | 0.3 | 2.4 |
| 26 | San Francisco Bay Area | 1.9 | 2.7 | — | — | — | — | | |
| 27 | Austin, Tex. | 1.5 | 2.4 | — | — | — | — | | |
| 28[a] | Austin, Tex. | — | | — | 4.3 | — | | — | 0.8 |
| 29[a] | San Francisco Bay Area | — | | — | 6.8 | — | | — | 1.1 |
| 30[a] | Orange County, Calif. | — | | — | 2.2 | — | | — | 2.1 |
| 31[b] | Portland, Oreg. | — | | — | 2.1 | — | | — | 0.5 |

NOTE: Estimates are for walking trips, unless otherwise noted.
[a] Comparison of single neighborhoods with highest versus lowest pedestrian-friendly characteristics on percentage of combined walking and cycling trips.
[b] Comparison of average of neighborhoods with three highest versus three lowest ratings of pedestrian friendliness on combined estimate of walking and cycling trips.

**TABLE 2 Regression Model Findings on the Relations Between Neighborhood Environments and Walking/Bicycling**

| Ref. No. | Geographic Location | Walking/ Cycling Outcome | Sociodemographic Variables Remaining in Regression Model | Neighborhood Characteristics That Contributed Significantly to Regression Model | Estimate of Model Fit |
|---|---|---|---|---|---|
| 35 | Various U.S. metropolitan statistical areas in | Probability of commuting to work by walking/bike | Number of autos owned (-) | Residing in center of city (+), higher density (+), commercial or other nonresidential within 300 ft (+), grocery or drug store >300 ft and <1 mile (-), adequate public transportation access (+), distance to work (-) | $\rho^2 = 0.532$ |
| 32 | Puget Sound area | Percentage of walking for 1. work trips 2. shopping trips | 1. No control variables enter model of walking to work 2. <1 vehicle (+), age (-), having driver's license (-) | 1. Percent walk to work: employment density at origin (+), population density at trip origin/destination (+), and mixed land use (+) 2. Percent walk to shop: employment density at destination (+), population density at trip origin and destination (+) | Percent walk to work adj. $R^2 = 0.31$ Percent walk to shop adj. $R^2 = 0.35$ |
| 29 | San Francisco Bay area | Number of walking/bike trips | None in final model of number of walking/cycling trips containing neighborhood variables | Neighborhood variables: specific neighborhood (+), having sidewalks/bike paths (+), and transit access (+) Urban attitude variables: pro-environment (+), pro-transit (+), desiring automotive mobility (-) | $R^2 = 0.0306$ for neighborhood variable model; $R^2 = 0.0946$ for neighborhood plus attitude variable model |
| 34 | San Francisco Bay area | Likelihood of taking walking/bike trips | Age (-), having driver's license (-), employed (-), autos owned (-), having a 'profes-sional' job (+), inverse of house-hold size (+), male (+) | Accessibility (how close jobs, services are) of origin and destination zone (+); mean non-work entropy of origin and destination (+), trip distance (-) | $\rho^2 = 0.219$ for control variable only model $\rho^2 = 0.266$ for neighborhood plus control variable model |

NOTE: + = positive association; - = negative association.

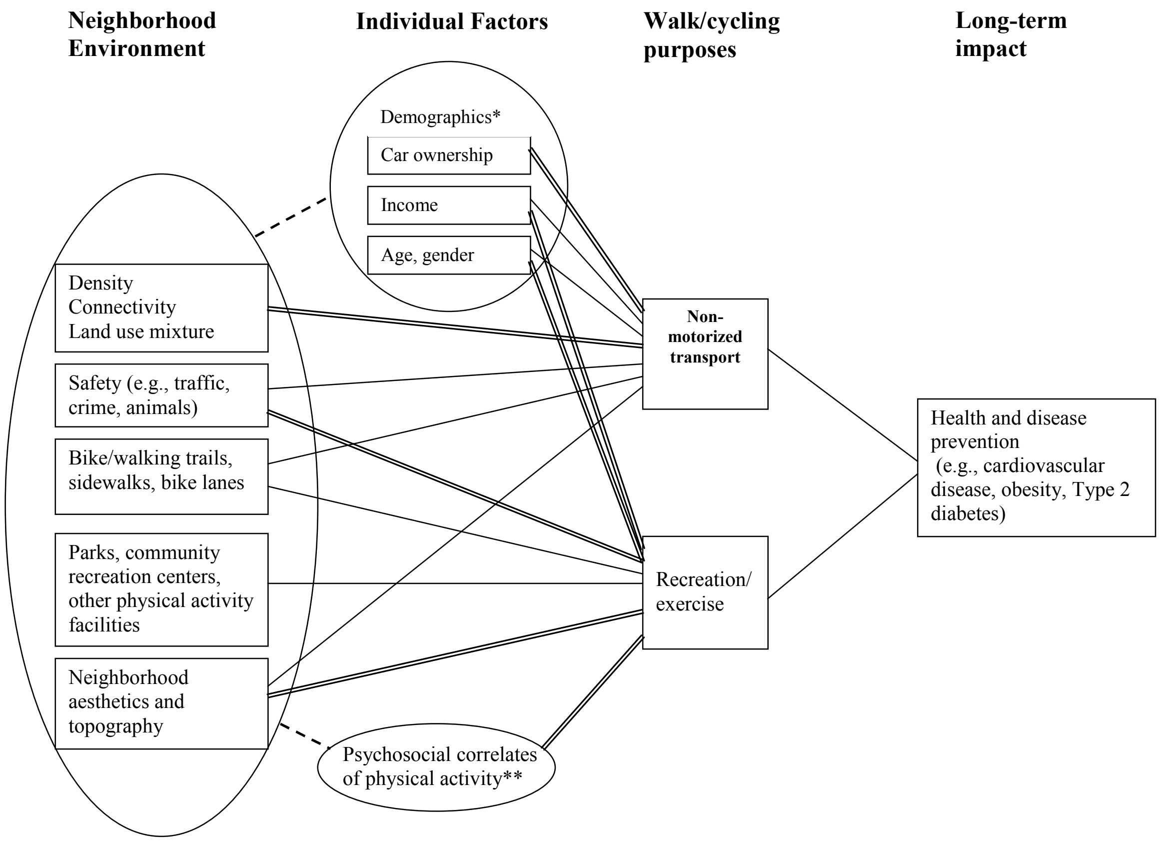


**FIGURE 1 A proposed ecological model of neighborhood environment influence on walking and cycling.**

(NOTE: Double lines denote stronger relations; single lines denote weaker relations; dashed lines denote mediated relations.
*Some examples of demographic variables are provided, but should not be considered comprehensive.
**Psychosocial correlates of physical activity would include, but are not limited to, such variables as self-efficacy, perceived benefits, perceived barriers, social support, and enjoyment of physical activity.

RESEARCH NEEDS STATEMENTS

# Transportation, Human Health, and Physical Activity

### 1. Tools and Methods to Integrate Health Outcomes and Nonmotorized Transport, Especially Walking and Biking, into Transportation Planning

**Problem Statement**
Bicycling and walking are not adequately included in the models and forecasting tools used by transportation professionals to plan the future of the transportation system at the local, state, and national level. Walking and bicycling, including transit, are short-changed in transportation planning, because these trips are undercounted and not adequately incorporated into travel demand forecasting models. Forecasting models are used to select and justify projects for regional transportation plans, but are usually unable to account adequately for the role of nonmotorized transport (NMT) within the overall transportation picture. Because of inadequate walking, bicycling, and health data, planning models and community impact statements are incomplete and inadequate for good decision making. Nor do economic models for transportation include walking, bicycling, and related health outcomes.

The proposed studies will create and evaluate tools that are needed to improve transportation planning and forecasting. They are dependent on completing initial studies to develop improved measures and data for NMT.

**Proposed Research**

1. Review existing travel demand forecasting models to identify examples in which NMT is best incorporated; identify barriers and facilitators to incorporation of NMT; and determine how best to integrate NMT into planning models. Develop modified approaches to travel demand forecasting that better include walking and bicycling, and pilot test and evaluate these tools in selected metropolitan planning organizations.
2. Develop and test tools to expand community impact assessments conducted as part of required environmental impact statements to include health outcomes, especially those related to walking and bicycling. New data collection approaches for NMT and models developed in Item 1 will contribute to the health impact calculation.
3. Develop and test tools and methods to incorporate the economic impacts of bicycling, walking, and health outcomes into economic modeling for transportation.

**Cost:** $750,000 (over 3 years)

### 2. Review and Synthesis of Research Literature to Identify Health Outcomes Associated with Transportation

**Problem Statement**
Transportation is a complex phenomenon that affects multiple dimensions of human health. This diverse body of research however has neglected the direct and indirect relationships of transportation and human health. This oversight has resulted in significant gaps in knowledge

and recognition of the extent of transportation effects on health, particularly as it pertains to NMT influences on physical activity (walking and bicycling).

**Proposed Research**

The recommended research focuses on conducting a modified meta-analysis to identify proven and possible relationships between transportation and the full range of human health issues. This study would synthesize existing research, provide a useful framework for examining these complex relationships, assess the level of rigor of the research methods and design, identify where more research is needed, and provide a scientific basis for on-going efforts to understand these connections in the following areas:

1. Health:
   - Mental, physical, and social health; and
   - Injuries and fatalities;
2. Health Care:
   - Access,
   - Costs, and
   - Services;
3. Behavior:
   - Nonmotorized travel (utilitarian walking and bicycling), and
   - Physical activity (recreational walking and bicycling).

**Cost:** $750,000
**Duration:** 36 months

### 3. Improving the Data Framework for Nonmotorized Travel

**Problem Statement**

Nonmotorized trips are the second largest category of trips, probably exceeding transit trips, and yet NMT trips are, in most cases, not are fully accounted for in the transportation planning process. Lack of consistent collection of NMT data precludes legitimate planning of the built-environment for land use or transportation systems. The U.S. Department of Transportation's Bureau of Transportation Statistics has recently documented the gaps in the NMT data, characterizing all of the current data as either fair or poor, and declaring all NMT research needs as medium or high priorities. In addition to transportation relevance, NMT is the only transportation mode that contributes to an individual's physical activity. NMT may make a substantial contribution to an individual's overall daily physical activity and thus substantially impact population health.

**Proposed Research**

The systematic accumulation of basic NMT data is a necessary first step to enable a future transportation planning capacity that is truly multimodal. Proposed research will create the data collection tools and methods needed to further clarify the NMT-related physical activity and health effects. To accomplish these goals research will need to:

1. Develop reliable, valid, and practical measures and data systems to collect more accurate NMT prevalence data and to capture missing elements of NMT trips. Examples of missing NMT elements include but are not limited to trip linkages to other modes, origin and destination, length of trip, time of day, seasonal and climatic variation, user demographics, purpose, different mode prevalence and determinants within overall NMT, and transport-related and physical activity-related preferences and attitudes.
2. Diversify the examination of environmental factors related to NMT. This could include creating prototype pedestrian and bicycle facilities maps, including but not limited to information on the land use, sidewalk access, and bike or walking trails, access to schools, street width, and traffic volume.

**Cost:** $1,500,000
**Duration:** 3 years

### 4. Sociodemographic Variation in Choices for Nonmotorized Transportation

#### Problem Statement

The ability of people to walk and cycle for transportation can have important effects on health; however, communities differ in their walkability and bikeability. Travel behavior and access to transportation options have rarely been examined for diverse sociodemographic subgroups. Research shows physical activity varies by income, education, race and ethnicity, health and disability, age, and gender. As such, these demographic variables should be the initial priority for study. It is very likely that transportation choices vary by these sociodemographic variables, but it is not predictable what those variations are. For example, low socioeconomic status (SES) groups report less leisure-time physical activity than high SES groups. However, it is likely that low SES groups do more walking for transport, possibly because they lack access to other transport options. On the other hand, middle class suburban dwellers report a substantial amount of leisure-time physical activity, but their only real transportation option is the car, so their NMT is low. These kinds of differences demonstrate distinct patterns of poor transport options that may affect NMT enough to influence health. To understand the impact of the environment and transportation infrastructure on health, it is necessary to develop a substantial database on sociodemographic characteristics of transportation users.

Transportation research has not collected adequate data on population subgroups to allow conclusions to be drawn about specific groups. For example, although those aged 85 and over comprise the fastest growing age group in the United States, the National Personal Transportation Survey does not have a large enough sample to support conclusions. The same can be said for most sociodemographic subgroups.

The information collected through this study will contribute to transportation planning that will ensure the full range of transportation options for all segments of the diverse American population. To enhance public health, data showing sociodemographic variations in factors related to NMT can guide environmental changes that will ensure that America’s diverse communities are walkable.

#### Proposed Research

Develop and validate in diverse populations those measures of travel behavior that adequately assess NMT as well as use of other modes.

Implement a national survey designed to adequately sample important population subgroups defined by sociodemographic factors, including gender, age (youth and older adults), education, income, race and ethnicity, and disability status. One option would be to expand the existing National Personal Transportation Survey. The survey should include valid measures of travel behavior, especially NMT, and assessments of access to transportation options and factors related to neighborhood walkability. Analyses should explore the extent to which NMT and other factors vary by socioeconomic characteristics. Transportation and public health professionals should be involved in the design, implementation, analysis, and dissemination of the study.

Results should be widely disseminated, with targeted distribution to transportation planners.

**Cost:** $1,000,000
**Duration:** 24 months

### 5. The Impact of the Roadway Environment on Perceived Safety and the Decision to Walk and Bike

#### Problem Statement

One of the most significant barriers to walking and biking is the perceived safety risk. This perception is believed to be tied to the design of roadways and the characteristics of the traffic along roads. The impact of the roadway environment on perceptions of safety and comfort and the impacts of perceptions on the decision to walk or bike are not well understood. Walking and biking are important forms of physical activity that promote health. Roadways that feel unsafe and uncomfortable may discourage walking and biking, whereas roadways that feel safe and comfortable and are aesthetically pleasing may encourage walking and biking. Major arterials and highways in suburban and rural areas, where less attention may have been given to accommodating pedestrians and bicyclists, are of particular concern. A better understanding of the links between roadway design, perceived safety and comfort, and the decision to walk or bike is important to efforts to increase walking and biking. This better understanding can provide a basis for more effective programs to retrofit existing roadways and possible modifications of design guidelines for new roadways. Improving actual safety along with perceived safety is also an important health goal.

#### Proposed Research

The primary question is how the roadway environment (roadway design and traffic characteristics) impacts the perception of safety and comfort of nonmotorized users and how that perception impacts behavior (the decision to walk or bike). The second question is how to best change the roadway environment and resulting perceptions to increase nonmotorized travel, especially walking and bicycling. These studies will require interdisciplinary teams of researchers. The tasks are

1. Conduct a literature review on pedestrian and bicyclist perceptions of safety in relation to roadway environment characteristics such as road width, traffic volume, landscaping, sidewalk design, parking, and roadway space allocation to each type of user.

2. Conduct experimental or quasi-experimental studies of self-reported perceptions of diverse subjects being exposed to various roadway environments.
3. Conduct observational studies of pedestrian and bicycle use in roadway environments with various characteristics that affect user perception of safety and comfort.
4. Conduct case studies of roadway environment changes that improved pedestrian and bicyclist perception of safety and comfort.
5. Make recommendations for translating these research findings into policies that will encourage more NMT.

**Cost:** $500,000
**Duration:** Over 2 years

**Collaborative Research Needs Statements**

**6. Health Effects of Transportation Emissions**
For full text, see Section 7 under Air Quality.

**7. Implications of Habit Formation and Retention, and Perception of the Built Environment on Time Use, Travel Choice, and Location**
For full text, see Section 3 under Land Use and Transportation.

**8. The Impacts of Locational and Travel Decisions of the Baby Boomer Generation on Future Transportation and Land Use Decisions**
For full text, see Section 4 under Land Use and Transportation.

**9. Investigating the Disaggregate Travel Behavior Effects of the Built Environment**
For full text, see Section 5 under Land Use and Transportation.

# Waste Management and Environmental Management (Recycling, Waste Reduction, Pollution Prevention, Brownfields)

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RESOURCE PAPER

# Waste Management and Environmental Management (Recycling, Waste Reduction, Pollution Prevention, Brownfields)

Carol LaRegina, *Michael Baker Corporation*

There are several strong trends associated with the evolution of waste management statutes and regulations. The significant changes include reduced emphasis on federal controls, with a concurrent increase in state involvement; alternate liability schemes that move from strict and joint liability to proportionate shared liability; increasing adoption of risk-based cleanup standards by states; the implementation of environmental management systems lessening the need for existing command and control regulatory systems; and life-cycle thinking in laws and regulations, in materials selection, and in facility/infrastructure design, which promotes sustainable transportation systems.

## CONTAMINATED MATERIAL IN TRANSPORTATION PROJECTS

Historical operations and waste management practices at transportation facilities have frequently resulted in adverse impacts on the environment. The emergence of environmental regulations governing management of contaminated sites in the 1980s required transportation agencies to identify environmental impacts and remediate affected sites. Remediation of transportation yards and facilities as well as contaminated sites encountered during planning and construction projects has involved inventorying, assessing, and addressing cleanup. Some agencies have faced sizable cleanup costs and liabilities from improper disposal that resulted in significant contamination.

In the past decade, many transportation agencies initiated programs to assess and, if necessary, remediate contamination at their respective facilities and in transportation projects. In some cases, agencies have taken a wait-and-see approach and acted only when compelled to do so by regulators. Those organizations with a proactive outlook and program that would be considered to represent state of the practice typically apply the following phased approach to remediating their properties and facilities:

- Inventory facilities,
- Assess past and current operations and waste management practices at those facilities to determine if the environment has been affected,
- Investigate sites where impacts may have occurred,
- Assess the risk to human health and the environment at affected properties,
- Prioritize actions that need to be taken based on relative risks,
- Identify feasible options for cleaning up contaminated media, and
- Clean up properties using the latest in available, cost-effective technology.

This process will continue for many more years because the process of addressing these problems is both time-consuming and resource intensive. To the extent that hazardous waste generation and hazardous materials usage is minimized at transportation facilities (primarily through environmental management systems, use of best management practices, and focused pollution prevention programs), the magnitude and extent of future contamination will be reduced.

The key topics likely to affect the foreseeable future with regard to hazardous materials in rights-of-way include cost recovery, brownfields acquisition and redevelopment, regulatory evolution, and the reuse or recycling of hazardous materials. With the exception of the inherently difficult issue of cost recovery, the future is likely to hold continuing research, education, and improvements on each of the other fronts. As with private-sector development, the incorporation of brownfields in rights-of-way has become more and more accepted and understood as not only a good "sustainable development" practice, but also a cost-savings practice as well. In cases where forward-thinking policies are not yet backed by strong and detailed regulations or by adequate financial or legal incentives, success stories and political and socioeconomic pressures should help motivate lawmakers to promulgate appropriate requirements and to alleviate financial or legal hurdles. Likewise, better legal precedents will hopefully be set such that the potential for liability is more consistently decided; thus helping administrators to better predict and manage risks.

Science and technology have continued to evolve and improve so that potential risks to the public and the environment can be better quantified and shown to be manageable without the need for avoidance or the expenditure of unreasonable levels of public resources for an extensive cleanup effort. The acceptability of in-place remedies such as natural attenuation and engineering controls has increased over the past several years and is expected to continue to gain acceptance.

In addition, the use of environmental database management systems, coupled with geographic information systems, is becoming an integral aspect of waste management practices. These tools help to provide communication and information access to various stakeholders; reduction of project costs through reduced efforts required by data analysis, entry, and maintenance; improved quality control and efficiency of deliverables; and support of an informed decision-making process through integrated data availability.

## BROWNFIELDS IN THE TRANSPORTATION WORLD

Putting brownfields back into productive use creates new economic opportunities and helps to revitalize communities. It also conserves open green space. Transportation is often a key in these redevelopment efforts for several reasons: good transportation is necessary; transportation-related uses are often considered for redevelopment or already exist in these areas, such as ports and railroads; and redevelopment allows for the use of existing infrastructure and services, thereby eliminating the cost of new public investment. The existing transportation infrastructure provides a competitive advantage over an undeveloped site. Necessary improvements are often limited to new turning lanes, pavement repairs, signal changes at intersections, parking improvements, and transit access. These changes can be considered minimal to the expensive upgrades typically encountered when connecting a new industrial park in the suburbs to an interstate highway. Brownfield development has the added benefit of growth with less traffic, because more trips can be undertaken by foot and by transit, placing less demand on roads and for trips on roads. The central location of brownfields means that trips are on average shorter, reducing demand for road space.

More than 40 states now have some type of voluntary program intended to encourage the cleanup and reuse of brownfields. The federal government has provided funding and implemented administrative reforms to reduce liability and cost barriers for the reuse of brownfield sites.

In 1995, the federal government began the Brownfields Economic Redevelopment Initiative. By mid-July 2000, the U.S. Environmental Protection Agency (EPA) had given almost 400 state, local, and tribal organizations pilot grants to assist with projects involving cleanup and redevelopment of brownfields.

In April 1997, the Federal Interagency Working Group on Brownfields announced that federal agencies would "integrate brownfields into their planning processes, ensuring that brownfields cleanup and redevelopment are eligible expenses for their project funds." A month later, the Brownfields National Partnership was launched, which included 15 federal agencies involved with brownfield efforts. The U.S. Department of Transportation (DOT) was one of the critical members of this partnership.

In 1997, the Federal Transit Administration (FTA) created a policy to provide incentives for transit agencies to encourage development around transit stations, bus terminals, intermodal facilities, and other transit properties in conjunction with joint development projects (private sector). The Transportation Equity Act for the 21st Century (TEA-21) offered additional relief to transit agencies by allowing transit operators to retain the profits from a property sale. Previously, all proceeds went to the U.S. Treasury. In 1995, the FTA launched the Livable Communities Initiative that awarded grants to communities for siting social and community-based services near transit stations. By 1998, $51 million had been given to 21 transit agencies. Funds for these grants are no longer available.

In 1998, as a result of the Brownfields National Partnership, 16 Brownfields Showcase Communities were designated as models to demonstrate the benefits of collaborative, focused, and coordinated activities between federal, state, and local entities. The intent is to produce environmental cleanups, stimulate economic development, and revitalize communities. These communities serve as models for cooperative efforts to support local brownfields initiatives. In October 2000, 12 additional showcase communities were designated.

In 1998, U.S. DOT issued a new policy encouraging state and local transportation agencies to pay for the cleanup of environmental contamination involved in transportation projects. This revised their previous policy that called for avoiding contaminated sites whenever possible. Now brownfields sites can be used if they meet all other appropriate criteria and are consistent with the transportation project. The Federal Highway Administration (FHWA) is currently revising their guidance document to clarify their position relating to brownfields. Finalization of this guidance is expected in 2002.

The U.S. DOT is encouraging state and local transportation agencies to consider brownfields use in transportation planning throughout the project development process. Transportation agencies need to look at access to planned brownfields redevelopment, the use of brownfield properties for transportation-related development, and new partnerships with state and local environmental and economic development agencies designed to attract additional resources and utilize transportation funding. The FHWA has several action items relating to program support and assistance that support the U.S. DOT brownfields position including

- Revising existing guidance to encourage acquisition and remediation of brownfields for transportation projects (as mentioned previously);

- Disseminating information on transportation-related brownfield success stories;
- Developing working partnerships with a broad range of state, local, and private partners relating to brownfields redevelopment;
- Creating cooperative partnerships between transportation, permit, and resource agencies to effective use brownfields;
- Developing a compendium of best practices for supporting brownfield redevelopment relating to transportation projects;
- Exploring liability issues relating to the level of cleanup needed to make brownfields reusable; and
- Producing a synthesis of brownfield cleanup efforts.

A research project is currently being conducted through the FHWA to determine the use of federal aid funds for brownfield projects across the country.

Although the U.S. DOT now encourages state and local transportation agencies to consider using brownfields, the transportation projects must still be included in the same transportation processes, such as inclusion in the metropolitan planning organization's (MPOs) 20-year transportation plan and the MPO's 3-year transportation improvement program. This often puts new brownfield projects at a disadvantage because TEA-21 requires that projects not be included in annual plans unless funding has been identified. States and MPOs usually have committed funds for years into the future. In 1998, the 16 brownfields showcase communities protested that U.S. DOT policies effectively locked important brownfield projects out of the transportation planning process..

The Transportation and Community System Preservation (TCSP) Pilot Program was created by TEA-21 and is administered by the FHWA with support from a working group that includes other U.S.DOT agencies (the FTA and Federal Railroad Administration) and the EPA. The intent is to support sustainability initiatives that balance the needs of transportation access with the promotion of economic development and environmental protection. TEA-21 authorized $20 million in fiscal year 1999 and $25 million annually for the next 4 years for states, MPOs, and local governments. These funds are to be allocated for projects that improve the transportation system's efficiency; reduce the impacts of transportation on the environment; reduce the need for costly future investments in public infrastructure; provide efficient access to jobs, services, and centers of trade; and identify strategies to encourage private-sector development patterns that achieve the program's goals. This is an opportunity to receive funding for projects that link transportation planning, implementation, and research to brownfield redevelopment. The U.S. DOT is looking for nontraditional partners for these projects; some of which may include public utility operators, social service agencies, community groups, environmental organizations, public health agencies, private land developers, and real estate investors. One example of a TSCP project involved a $700,000 grant in 1999 to the New Jersey Institute of Technology and the North Jersey Transportation Authority to facilitate the redevelopment of abandoned brownfields by freight-related business, because of the increased economic growth in trade handled through port, airport, and rail terminals. The purpose of the project is to provide access to brownfields, recruit businesses, and create jobs.

The Brownfields Revitalization Act, signed by President Bush on January 11, 2002, provides liability protection for prospective purchasers, contiguous property owners, and innocent landowners and authorizes increased funding for state and local programs that assess and clean up brownfields. Funds will be doubled from $98 million to $200 million to help states and communities clean up and revitalize brownfields sites. An additional $25 million is provided for urban redevelopment and brownfields cleanup through the Department of Housing and Urban Development.

Brownfield redevelopment often results in attracting private development; in particular, when transportation improvements are involved. Several successful transportation projects and brownfields from across the country have shown that improved access to brownfield sites can result in the construction of industrial and business parks, manufacturing facilities, other commercial centers, and public service centers. Although financing is not easy, the collaborative efforts of federal, state, and local agencies, as well as private partners, have resulted in funding possibilities that did not exist a few years ago. There are often "package deals" associated with redevelopment projects that include tax incentives and liability protection for private investors. These agencies need to strive to continue to make brownfields a priority in their policies and funding mechanisms. The reuse of brownfields has tremendous potential to revitalize communities, produce jobs, improve economic growth, protect the environment, increase the local tax base and property values, and improve the quality of life. Specific transportation-related benefits include reducing trip times and lengths, air emission reduction, more efficient use of existing infrastructure, support of transit systems, and more viable walking and biking choices.

**ENVIRONMENTAL MANAGEMENT SYSTEMS: MOVING TOWARD A TOTAL SYSTEMS APPROACH**

Until the late 1990s, the transportation industry viewed environmental issues from the standpoint of "the project." Resources were devoted to ensure that projects complied with the National Environmental Policy Act, FHWA, and other federal, state, and local environmental laws and regulations. This perspective has begun to change and transportation organizations are beginning to look internally to evaluate how they can improve the environmental performance of their operations while being more cost-efficient. The private sector is more heavily engaged in evaluating and adopting environmental management systems (EMSs), such as the International Organization for Standardization (ISO) 14000, to improve and integrate the environmental aspects of their operations. Recently, public agency facilities at all levels—federal, state, and local—have begun implementing EMSs in an effort to reduce operational costs and to improve overall environmental performance. Several public transportation agencies have begun to assess the benefits of EMS programs.

In 1997, the EPA sponsored the first of two initiatives to help government agencies test the applicability and benefits of an EMS on environmental performance, compliance, pollution prevention, and stakeholder involvement in government operations. This program was referred to as the USEPA EMS Pilot Program for Government Entities. Nine local government entities were involved with the first initiative, including the New York City Transit (NYCT)–Capital Program Management (CPM) Department. These entities experienced improved overall environmental performance in both regulated and nonregulated areas, expanded pollution prevention opportunities, improved compliance, and enhanced operational control and efficiency.

The NYCT's EMS evolved from a checklist and procedure to an ISO 14001-certified system. Their CPM Department plans, designs, and manages the construction of capital work for the NYCT system. NYCT is the largest mass transit system in the United States and among the largest mass transit systems in the world. The EMS provides the framework for managing the environmental aspects and impacts of NYCT's capital program, which is annually funded at more than $2 billion.

In March 1999, CPM received a third-party audit and was found to be ISO compliant, becoming the first public agency in the United States and the first mass transit agency in the world to receive ISO certification. They continue to maintain their ISO certification through 6-month audits conducted by a third-party auditor.

The success of the EPA's first program prompted a second initiative beginning in March 2000. Completion of this initiative is expected in 2002. Of the 14 participants in this program, 3 are transportation-related agencies: Port of Houston (PHA), Texas; Tri-County Metropolitan Transportation District (Tri-Met), Portland, Oregon; and New Hampshire DOT. Each of these agencies selected a segment of their organization to participate in the EMS process: PHA, Barbours Cut Container Terminal and the Turning Basin Terminal's Central Maintenance Facility; Tri-Met, eight maintenance facilities; and New Hampshire DOT, the Bureau of Traffic. Information available about this program indicates that the agencies are experiencing benefits in the areas of natural resource conservation, energy efficiency, and increased recycling rates, and are identifying ways to improve and streamline internal operations.

The EPA is encouraging organizations to use EMSs that improve compliance, pollution prevention, and other measures of environmental performance. They continue to evaluate efforts to learn more about which EMS elements and applications are most effective. The EPA has required some companies with compliance problems to develop EMSs when they settle enforcement cases, although it is not basing any regulatory incentives solely on the use of EMSs or certifications to ISO 14001. In August 2001, the EPA issued an "Action Plan for Promoting the Use of EMSs." The three goals of this plan were: (1) promote wider adoption of EMSs across a range of organizations and settings, (2) promote excellence in the practice of EMSs inside and outside the agency, and (3) integrate EMSs more fully into agency programs and activities. Each of these goals has four elements, which further describe the EPA's proposed actions. One of the elements under Goal 1 is to provide recognition and incentives to organizations with effective EMSs. The initial phase, launched in June 2000, is the National Environmental Performance Track Program, with a strong EMS as a required core element. The EPA expects to incorporate EMS requirements into other programs that may be established to reward or encourage improved environmental performance in the future.

The Pennsylvania DOT is in the process of implementing an EMS that will conform to the ISO 14001 international standard. Their program, referred to as the Strategic Environmental Management Program (SEMP), will integrate the strategic environmental management concepts of pollution prevention, energy efficiency, and environmental accounting with the ISO 14001 EMS performance requirements. Pennsylvania DOT is currently piloting the SEMP in one of its 11 maintenance districts. This maintenance unit is scheduled for certification by the end of 2002. The entire department will ultimately be brought into the SEMP and is scheduled to be ISO-conforming by 2005.

To integrate efficient management and minimization of waste within the transportation organization's operations and maintenance, an all-inclusive assessment of its activities, products, and policies need to be performed to determine levels of interaction and impacts to the environment and human health. The results of such evaluations will be used to develop EMSs for the operations and maintenance of transportation agencies and not just for specific projects or programs. The EMS will be used not only as a monitoring and compliance tool but also as a way of achieving and improving a desired level of environmental performance.

To ensure the effectiveness of the EMS, transportation agencies will need to regularly review and evaluate information such as the results of audits, corrective actions, current and proposed legislation, results of monitoring, and complaints. This review will allow transportation agencies to review their operations and systems and to ensure that they are and will remain suitable and effective.

It is important to note that an EMS should not be developed as an add-on program. Its effectiveness will depend on the consistent, systematic control of operations, procedures, products, or services that can have a significant impact on the environment. Although an EMS is obviously concerned with environmental performance, effective management of the total transportation agency is the ultimate goal.

An EMS is viewed as an excellent opportunity to build environmental management into the daily business operations of transportation organizations. Some of the expected benefits include reduced disposal costs, reduced liability costs, fewer permits, fewer inspections, improved compliance, improved worker health and safety, and environmental considerations integrated into organization decision making. One of the most important benefits is improved financial performance, achieved through incorporating programs that enhance operations efficiency, reduction of labor hours, and reduction of overall liability. An EMS can be considered a good return on investment, not only in financial terms, but also in community relations and sustainability.

**BENEFICIAL REUSE OF MATERIALS IN TRANSPORTATION PROJECTS**

The transportation sector uses millions of tons of material every year. Some of these materials are used for construction, operation, and maintenance, whereas some are scrap or secondary materials. The state of practice and the future possibilities regarding transportation materials, therefore, relate to two streams: primary and secondary materials.

Management of secondary materials such as asphalt, concrete, plastics, and paint has traditionally been limited to landfill disposal. Transportation agencies have perceived these obsolete materials as costs, which are especially high in areas with high landfill tipping fees or long transport distances to landfills. Materials that have had a high value at the end of their useful life (such as steel, aluminum, copper, and other metals) have been recycled and to a limited extent reused (such as old steel bridge girders transported to another site) in other applications. The key to the success of metals recycling and reuse has been the existence of reverse logistics systems (collect the metals and transport them to processing plants) and markets that are ready to absorb these materials. Whenever markets and reverse logistics are found for high-volume transportation materials, recycling will take place without outside intervention. For example, asphalt pavements are increasingly recycled on-site, as well as in off-site asphalt plants, into new pavements. The existence of standards, or at least the lack or regulatory obstacles, also stipulates the use of secondary materials for new applications.

To save economic and environmental costs, transportation material utilization also has the goals of pollution prevention, dematerialization, waste minimization, reduction of nonrenewable and renewable resource consumption, and reduction of the environmental and human health effects of materials use. Some actions to implement these goals in construction, operation, and maintenance have lead to environmentally beneficial practices such as removal of lead from paint. However, most of these goals are still vaguely defined and are missing action plans.

Some state DOTs take an active role in the evaluation of products and materials that are proposed for recycling in transportation applications. The advantages to DOTs that use recycled materials include economic savings (lower material costs and lower disposal costs) and environmental enhancement. The environment benefits by extending the life of natural resources, reducing air and water pollution, and by extending landfill life. Some of the recycled materials that are currently used in transportation projects include scrap tires, fly ash, waste glass, steel slag, plastic, reclaimed asphalt and aggregate material, spent foundry sand, coal bottom ash, baghouse fines, cement kiln dust, roofing shingles, crushed concrete, blast furnace slags, woodchip compost, aluminum, recycled newspaper, and composted sewage solids. Available information indicates that California, Massachusetts, North Carolina, Pennsylvania, and Texas have active recycling programs.

The following are the five key areas relating to using recycled materials in transportation projects: testing and research, specifications, project development, communication, and contract bidding. Each of these areas will be further described.

Further research is needed to evaluate the existing and new uses of recycled materials. The environmental implications of using transportation materials need to be systematically assessed and analyzed. Research needs to be conducted concerning the benefits and costs of recycling and reusing specific secondary materials and can be achieved using life-cycle environmental and costs analysis. Although the benefits might be apparent for some materials, they may be hidden for others due to a lack of systems view. For example, the environmental benefits of recycling some materials may outweigh their current market costs. Once the environmental impacts are assessed, improving the processes associated with the manufacturing and usage of transportation materials should minimize the environmental footprint of the materials. The technical performance of materials should not be compromised in this process. A good deal of research has been done on many recycled materials through organizations such as the FHWA, the Recycled Materials Research Center (RMRC), the National Cooperative Highway Research Program, state DOTs and industry associations. However, there is still more work that needs to be done.

Uniform material and product specifications, bidding specifications, and user guidelines for recycled materials need to be developed. Specifications should not specify the origin of the material, but should simply be based on performance characteristics. Recycled material may inadvertently be put at a disadvantage by language used in specifications. One of the RMRC's current research projects involves developing specifications for using recycled materials in transportation applications.

Transportation managers need to identify projects that could use recycled materials and then encourage staff members to incorporate such materials into the project. Decision makers, designers, and material procurers in the transportation industry need to be informed and educated about the environmental impacts of their choice of materials.This will require easy-to-use, transparent, yet comprehensive guidelines, methods, and computer-based design and management tools. Another research project being conducted through the RMRC, which involves the development of a life-cycle analysis model and decision-support tool for selecting recycled versus virgin materials for highway applications, may be of assistance in this key area.

Education is needed to increase public awareness and trust, and to relieve fears about the use of certain materials. These materials must no longer be viewed as "waste," with its negative connotations, but as resources. One common misconception is that industrial by-products are all excessively dirty or contaminated. Some materials, which are perceived to be "toxic," are not any worse and actually may be better than currently used materials. Such information needs to be provided to transportation employees, local governments, and the general public by means of various media.

Transportation agencies need to evaluate contract legal bidding requirements and develop innovative ways to allow DOTs to specify the use of recycled materials in transportation projects (including construction and maintenance). In addition, incentives need to be provided to contractors who use these materials.

The RMRC was created in 1998 to promote the use of recycled materials in highway projects. It is a partnership between the University of New Hampshire and the FHWA and was initially funded for 6 years by TEA-21. The mission of RMRC is to act as a catalyst in reducing barriers in the use of recycled materials by working cooperatively with federal and state officials; testing, evaluating and developing guidelines; conducting outreach activities; and encouraging increased use of recycled materials by analyzing potential long-term considerations that may impact performance. The RMRC expects to have 30 research projects funded and conducted in the first 6 years of operation. Currently, there are 15 projects under way, with 2 of these projects being completed. Some of the research projects are conducted in-house, whereas others are awarded through a national request for proposal.

The FHWA is promoting recycling and has created a recycling team whose role is to increase the FHWA's and their partners awareness of existing recycling; identify, foster, and promote research to develop or test new technology; encourage the review, evaluation, and advancement of emerging technology; identify and help overcome barriers; and facilitate coordination between state transportation and environmental agencies, the EPA, and industry.

## EMERGING ISSUES IN THE 21ST CENTURY

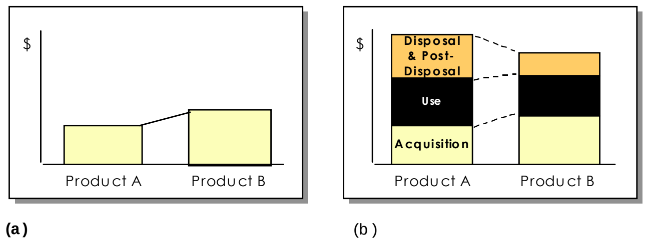
There are many emerging issues facing the transportation industry, some of which are associated with waste management. Sustainability is an issue that the transportation industry is beginning to examine. All aspects of transportation, including policies, procedures, operations, resource use, and community relations affect the natural and human systems now and for future generations. Pollution prevention and life-cycle thinking are important tools used to measure the performance of individual transportation organizations.

Smart growth is another critical issue tied to sustainability. The issue of urban sprawl is reaching critical mass on both the grassroots and national political scene. Improving and increasing the density of transportation systems in urban areas will require the use of environmentally impaired properties. The use of various technologies and approaches will be needed to meet the increasing demands of urban transportation systems.

The widespread, rapid, and easy access to information will transform how the transportation industry addresses waste management issues. Community groups and informed citizens will have access to detailed information on the generation and management of waste associated with transportation organizations, systems, and projects. How the industry responds to issues will be driven to a much greater degree by public consensus and sentiment as compared with regulatory drivers or with government command and control systems.

A major challenge to transportation professionals will be to move the process of waste management more into the mainstream of the transportation mission. If the transportation industry can address waste management proactively at all levels (planning, construction, operations, and maintenance), then waste management will be more likely viewed as a tool rather than a liability to the core mission of building and maintaining successful transportation systems.

**FIGURE 1 Considering real life-cycle costs: (*a*) if only acquisition costs are considered, Product A seems like the better choice; (*b*) in the long run, Product B is more cost-effective.**



RESEARCH NEEDS STATEMENTS

# Waste Management and Environmental Management (Recycling, Waste Reduction, Pollution Prevention, Brownfields)

### 1. Compile and Evaluate Existing Technologies to Develop Best Management Practices Addressing Prevention and Remediation of Contamination from De-icing Operations

**Problem Statement**

Throughout the country, many departments and agencies have removed ice from transportation facilities for many years due to safety considerations. Although much research has been performed, gaps in the research remain.

Specifically, storage, handling, and the use of de-icing compounds continue to cause contamination that affects water supplies, resulting in remedial, compensatory, and regulatory action. Additionally, an accumulation and evaluation of prior research has not been performed.

**Proposed Research**

1. Identify and accumulate prior research relating to environmental issues associated with de-icing compounds.
2. Evaluate information accumulated in Item 1 for gaps in research relating to storage, handling, and use of deicing compounds and remediation of soils and water contaminated by de-icing compounds.
3. Provide recommendations for:
   - Best management practice (BMP) for the storage, handling, and use of de-icing compounds and solutions to prevent contamination of soils and waters;
   - Additional research is needed concerning storage, handling, and the use of de-icing compounds, and remediation technologies for contaminated soils and water; and
   - Remediation of soils, surface water, and groundwater affected by de-icing compounds.

**Cost:** $250,000
**Duration:** 18 months

### 2. Improving the Acceptance of Recycled Material in Transportation Projects

**Problem Statement**

Each year millions of tons of construction debris, including soil, rock, asphalt, and concrete, along with other industrial waste and by-products are generated.The management, reuse, and disposal of some of these materials pose a serious challenge for the transportation sector. The federal government encourages the appropriate recycling of these materials; however, there is concern over the performance of recycled materials and products made from recyclables. This research would help raise the acceptance level of the use of recycled materials by all transportation sector stakeholders for the construction, operation, maintenance, and improvement of the nation's transportation infrastructures.

Although the contamination level of these materials varies, the general perception is that transportation projects constructed with recycled materials are unsafe and hazardous to human health and the environment and should not be used in place of virgin materials. This attitude makes it very difficult to get project approval and public acceptance for using these perceived contaminated materials in transportation projects.

### Proposed Research

Research will be conducted to identify the level of knowledge and areas of misunderstanding among transportation stakeholders concerning the use of recycled materials in transportation projects. Research will include a review of current proactive recycling promotional programs that may be used to further educate transportation stakeholders. For public awareness, additional education programs should be developed to eliminate the misunderstandings over the use of recycled materials in the transportation sector.

The research will be conducted according to the following:

1. Develop and conduct a survey of engineering design professionals to identify barriers to the use of recycled materials in transportation projects.
2. Develop and conduct a survey of public stakeholders to identify their perceived negative connotations of the use of recycled material.
3. Review current proactive recycling promotional and educational programs to use in the development of a model public awareness program.
4. Summarize findings from surveys and develop a broad-based public awareness and education campaign to demonstrate the benefits of recycled material use.
5. Identify and partner with appropriate local, state, and federal resource agencies or trade organizations to develop and implement a pilot project. Disseminate results of the pilot program to appropriate stakeholders.

**Cost:** $500,000
**Duration:** 30–36 months

## 3. Benchmarking of Environmental Management Systems in Transportation Organizations

### Problem Statement

Transportation agencies and related organizations are spending a significant amount of economic and human resources in managing environmental issues related to their operations. A significant amount of these resources are spent because of inefficient internal processes and management practices conducive to reducing and eliminating unnecessary environmental impacts and risks.

There are a number of transportation organizations that are implementing environmental management system (EMS) programs; however, there are no mechanisms in place to avail and disseminate information on the benefits of these programs. Therefore, there is a need to document the realized environmental benefits to assist other transportation organizations in improving their environmental management performance and stewardship.

The research need presented above is in line with EPA's Action Plan for Promoting the Use of EMS Programs (EPA August 2, 2001) and its first goal of wider adoption of EMS across a range of organizations and settings.

**Proposed Research**

1. Conduct a comprehensive benchmarking of EMS programs being implemented by transportation organizations within the United States and other countries. This evaluation should identify and quantify the benefits of these programs from the following standpoints:
   - Cost,
   - Energy conservation,
   - Waste reduction,
   - Employee productivity improvement,
   - Risk reduction, and
   - Customer satisfaction.
2. From this benchmarking effort, identify and disseminate the environmental BMPs that contributed to the realized benefits of the six elements described in Step 1.

**Cost:** $600,000
**Duration:** 18 months

### 4. Development of a Web-Based Cost-Benefit Analysis Model for Environmental Products and Technologies Used on Transportation Projects

**Problem Statement**

The use of certain products and technologies on transportation projects currently depends on a variety of factors including cost, availability, environmental benefits, ease of use, community acceptance, and political acceptance. However, the ability to quantify the overall cost-benefits of products (beyond initial purchase and construction costs) is difficult because of the lack of suitable user-friendly support tools. This quantification is needed to justify the use of products or technologies to management.

This challenge is often evident at the operations level, where the person most knowledgeable about the product or technology and advocating its use is required to justify the choice (in financial terms) to upper management. Thus, a user-friendly, easily accessible computer model that allows rapid assessment of options to determine the most cost-effective environmental solutions for design, implementation, maintenance, or reuse of products or technologies is needed.

**Proposed Research**

*Phase I: Identify Analysis Models*

Identify cost-analysis and economic models that may perform the required basic modeling functions. Assess the ability of each model to accept a variety of inputs, undertake meaningful comparisons, perform a variety of financial analyses, and provide quantitative outputs useful for rational decision making. Determine features that may be suitable for incorporation into model development.

*Phase II: Model Development and Design*
Using information obtained in the first phase of the study, develop and design a web-based model that can be updated and customized for specific applications, yet is able to accommodate changes to input parameters and outputs. Above all, the model needs to offer the flexibility of being usable by individuals at all levels, thereby allowing choices of the level of analysis and types of outputs. The model should incorporate the following parameters:

- Initial costs,
- Operation and maintenance costs,
- Disposal costs,
- Replacement costs,
- Annual depreciation costs,
- Cost of money (i.e., inflation rate),
- Time period (i.e., life expectancy), and
- Sensitivity analysis.

This phase should also include verification testing of a beta version by selected experts followed by pilot testing of the web-based model using real data remotely accessed by the end-user.

*Phase III: Model Enhancement*
This phase would require further significant development to produce an enhanced model that has the ability to analyze real life-cycle costs and benefits in areas such as:

- Productivity,
- Health,
- Emissions reductions,
- Air quality improvements,
- Materials and resources, and
- Energy consumption.

The end-users of the model will be transportation and environmental sectors and stakeholders.

**Cost:** $850,000
**Duration:** 36 months

### 5. PREPARE A COMPENDIUM OF SUSTAINABLE DESIGN IDEAS FOR USE BY A WIDE RANGE OF TRANSPORTATION SEGMENTS

### Problem Statement
There is an increasing awareness of how "smart design" concepts can reduce the environmental impact of transportation systems and projects. Progress to date has been the result of ad hoc efforts by motivated individuals, companies, and agencies that have identified cost savings and efficiency enhancements made possible by applying sustainable design concepts. Research is needed to identify, classify, and describe high value, practical sustainable design ideas and

approaches that a broad range of transportation segments can reference in the design and planning of transportation systems and projects.

**Proposed Research**

1. Benchmark domestic and international organizations that use sustainable design concepts in their planning and design processes.
2. Create a reference database of sustainable design ideas and approaches that have the potential to enhance transportation projects.
3. Create a system that would enhance the ability of the transportation industry to access the database and constantly update it with newly developed practical sustainable design approaches.

**Cost:** $500,000
**Duration:** 24 months

### 6. Create a Methodology to Integrate Sustainable Design Concepts into Transportation Projects and Infrastructure

**Problem Statement**

The ideas or solutions of sustainable design that are generally available pertain to manufacturing operations and office and residential building design. Although the basic principles of sustainable design are the same, the specific needs of transportation are not addressed. Therefore, research needs to be conducted to outline the sustainable design requirements for transportation programs based on the following elements:

- Conserving energy use of renewable energy sources,
- Enhancing indoor environmental quality,
- Conserving materials and resources,
- Improving operations and maintenance, and
- Conserving water.

Also, the research needs to identify the most efficient means of integrating these concepts into the design of transportation projects and systems.

**Proposed Research**

1. Identify sustainable design methodologies that can be applied to a broad range of transportation organizations.
2. Identify a pilot project to apply the methodology.
3. Work with sponsoring agencies to implement the methodology and monitor the pilot project.
4. Develop a summary of lessons learned and create a system to allow effective dissemination of lessons learned to all stakeholders.

**Cost:** $900,000
**Duration:** 30–36 months

## 7. Provide an Interactive, Web-Based Tool That Promotes the Greening of the Transportation Industry's Procurement Practices

### Problem Statement

Current decision making in the procurement and user divisions of the transportation industry is not based on the real life-cycle cost of a product. Rather it is only based on the first cost and does not account for other costs as illustrated in Figure 1.

This problem is dramatically complicated by the complexity of the transportation supply chain. Suppliers to highways, bridges, facilities, ports and waterways, airports, railroads, and mass transit systems all have a direct effect on the total life-cycle cost of the purchased product. This is a direct result of the methods and materials used in fabrication, the movement of products to their point of use, the life expectancy of the products, the operation and maintenance requirements of the products (or assembled components), and the requirements of disposal or reuse at their end of life. Research is needed to develop tools promoting the purchase and use of those environmentally friendly products that have the lowest total life-cycle cost.

### Proposed Research

1. Map various transportation segment supply chains, including expected waste streams.
2. Identify existing reference materials and research that present environmentally friendly alternative products that are typically used in the transportation industry, by segment.
3. Develop a web-based decision-making tool using a life-cycle cost model that can be used by procurement divisions of transportation sector companies.

**Cost:** $900,000
**Duration:** 24 months

# Water Quality and Hydrology

## WORK GROUP PARTICIPANTS

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RESOURCE PAPER

# Water Quality and Hydrology

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The committee members for Water Quality and Hydrology used an integrated approach to discuss research needs for the Transportation Research Board (TRB). This approach was defined in the TRB Millennium Paper prepared by John Sansalone for the Hydrology, Hydraulics, and Water Quality Committee (A2AO3), chaired by Peter Smith (2000). The following is quoted from the abstract for that paper:

> Water will continue to play a crucial role in transportation system development, albeit a sometimes-adversarial role as our current constructed urban, highway, waterway, air transport, and rail transportation environments increasingly compete with our natural environment. However, a new holistic paradigm is developing with respect to the role of water and ecological sustainability for transportation systems and the environment in the new millennium. Revolving around water as a common theme, this paradigm will encompass the fundamentally related areas of hydrology, hydraulics and geomorphology, and water quality towards a goal of ecologically sustainable transportation.

## RESEARCH NEEDS DISCUSSION

The committee was concerned with addressing issues running the gamut of the hydrologic cycle. Committee member concerns ranged from the very small and very short, to the very large and very long. Research may be applicable at the sand grain, even molecular level, as well as including whole river basins or at least large watersheds. Scale effects and scalar integration are areas that present continuing challenges for scientists, engineers, managers, and regulators.

The committee focused on the rainfall and runoff part of the hydrologic cycle, considering fundamental physical, chemical, and biological processes that operate during runoff events. It is during these events that critical hydraulic conditions occur that lead to scour, channel instability, and other impacts.

Recognition has been given to the unique setting created by transportation corridors by which these fundamental physical, chemical, and biological processes operate. Surface transportation corridors are a highly engineered environment where due consideration has already been given to hydraulics, hydrology, and, in some instances, water quality. Under existing regulations there is a real opportunity to control runoff and a specific responsibility to address both quality and quantity issues in the environment for these transportation corridors.

In rainfall and runoff analysis it is important to consider both the landscape over which the runoff occurs and the system receiving that runoff. Landscape issues of particular concern include changing land use, the creation of impervious area, and increasing the number and complexity of sources of contamination. Consideration for a receiving system starts by recognizing/defining the receiving system. Receiving systems can be lakes, estuaries, oceans, or a network of channels that carry runoff. It is important to recognize that each type of receiving system has physical, chemical, and biological/ecological characteristics that are type related. This may be affected differently by runoff from transportation corridors. Intuitively, the first system type receiving runoff will likely be a small channel that initially collects rainfall and then provides the conduit for transport across the landscape. Statistically from literature, approximately 85% of the primary receiving waters adjacent to urbanized areas are rivers (Heaney et al. 1980). Although large rivers are the primary receiving system for many urban areas, the runoff to these large rivers does flow through small tributaries, so more than 20% of the urban rivers may fall into the "small" category.

When considering transportation corridors, most "channel crossings" will be small channels, not large rivers. Large lakes tend to dominate, making up approximately 5% of the total urban area receiving waters. Estuaries and oceans make up approximately 10% of the total urbanized area receiving waters and about one-half of these are open oceans or beaches. The remaining areas receiving waters are classified as estuaries, having depths of between 3 and 10 m (10 and 30 ft). Lakes and estuaries can be severely affected by runoff, because these receiving systems have limited dilution or diluting circulation. This is particularly true for small ponds and backwaters (comprising approximately 0.5% of all the urban receiving waters). Shallow estuaries or bays less than 3 m (10 ft) deep (comprising about 0.5% of all the urbanized receiving waters) are subject to runoff from bridges; particularly bridges with high vehicle usage.

In summary, small streams and rivers that have limited capacity to assimilate the changes produced by developing urban areas and their transportation networks will be the receiving systems most affected by runoff from transportation corridors. If an emphasis in transportation research is placed on the most numerous receiving system types, then large rivers should be a research priority. If receiving systems that are most severely affected by urban runoff are emphasized, then small systems, including ponds, wetlands, and estuaries, as well as rivers, should receive research priority.

The primary focus of research needs analysis from 1996 emphasized the practical application of the fundamental understanding of physical, chemical, and biological/ecological processes operating in receiving systems; independent of receiving system type. The 1996 panel considered typology issues (e.g., wetlands) to develop research priorities based on critical receiving system types.

General research needs in any type of receiving water include

- Continued development and understanding of fundamental physical, chemical, and biological or ecological processes operating in receiving systems;
- Development of a better understanding of the influence of transportation corridors on watershed hydrology, specifically modification of transport and transport time scales;
- Development of techniques to identify sediment sources in watersheds, and characterization of transportation corridor contribution to channel stability;
- Characterization of how site-specific conditions affect fundamental processes, considering both the effect of runoff on processes and process effects on runoff; and
- Collection of consistent data into a readily accessible archive that will support advancements in the understanding of both fundamental processes and site-specific impact.

Again, there is good advice in the Millennium Paper cited previously! Quoting from the abstract to that paper

> Looking forward, there are four developments required to advance this (holistic) paradigm. The first is development of fundamental and viable physical–chemical–biological measurement technologies at scales from a micro-scale (micro-hydrologic) to a watershed/global scale. The second is advances in data acquisition, real-time data transmission, and imaging technology across these scales. The third is improved understanding of physical–chemical–biological mechanisms and modeling of fundamental processes involving the interaction of atmospheric, surface, and subsurface water with transportation infrastructure and activities. The fourth is cost-risk management to provide design guidance for micro-hydrologic to regional scales.

The challenge for the panel is to recognize that there may be a logical and needed progression of activity that often starts with fundamental research, progresses through applied research, addresses technology transfer, and is then applied through proof in practice. All of these steps are open for discussion and should be considered as a part of panel deliberations.

**Receiving System Focus for a Research Needs Assessment**

A holistic focus for discussions on receiving systems will consider a range of relationships that exist on the landscape, during the transfer of water across the landscape to the receiving system, and in the receiving system itself. The general characteristics of runoff and the specific characteristics of runoff in transportation corridors have been well documented, but the effects of runoff on receiving systems are still poorly defined. This is particularly true when integrated physical, chemical, and biological/ecological effects are assessed. The best guidance is to look to urban runoff literature to connect transportation corridor characteristics with environmental change. There have been several research needs assessments in this area completed over the past 10 years (Heaney 1986; CH2MHill 1990; and several ASCE Urban Water Resources Research Council, Engineering Foundation Conference Proceedings). In the past, one characteristic of these reviews has been the focus of regulatory and management contexts for which receiving system issues have been identified. Transportation agencies often identify regulatory compliance as one of the major drivers for research. The regulatory focus has recently been sharpened with the stormwater component of the National Pollution Discharge Elimination System (NPDES) program. There is a renewed emphasis on the control of runoff from a range of nonpoint sources, including transportation corridors. The U.S. Environmental Protection Agency has adopted a biological criteria (biocriteria) approach (EPA 1992) and renewed emphasis on watersheds in the Watershed Protection Approach (EPA 1993). The focus of water quality planning includes issues of restoration, requiring better impact analysis and recovery indicators (e.g., Watershed ’96 Proceedings and EPA 1995).

It is necessary to consider research needs from many sources. Need statements to protect receiving waters should be considered for regulatory and management programs connecting watershed issues with control strategies for runoff quality and quantity. This holistic approach will require advances in physical, chemical, and biological areas, and in integrative watershed-based approaches to water quantity and quality control.

**Needs in Physical Analysis and Assessments**

Physical effects have been well characterized in some areas and are uncertain in others. Storm-flow volumes and flow-return frequency have been well characterized; however, hydrograph separation techniques estimating the origin of flow in rivers requires further research. Channel substrate size, bank erosion, channel size, and form are associated with flow volume and flow frequency, but well-tested predictive models that relate flow to these channel characteristics (geomorphology) are unavailable. The effect of flow volume and flow frequency on channel form and stability is not clearly understood. This is particularly important when restoration or rehabilitation of damaged or unstable channels is needed—no well-developed procedures are available that effectively connect engineering capabilities with channel geomorphology to ensure that long-term design or management goals can be met.

Temperature changes associated with runoff on paved areas as well as the effect of detention basins on receiving water temperature conditions has been documented. However, temperature is often overlooked as a physical characteristic of receiving waters. It is possible to model temperature effects of urban runoff, but a number of issues are unresolved when temperature is related to chemical or biological processes in receiving waters. Available models are often site-specific or limited in scope (e.g., addressing only summer season issues).

Uncertainty exists in identifying sediment sources and defining transport rates and residence time of sediment in receiving waters. Although sedimentation is primarily related to streams and rivers, research attention should be given to the effects of transportation corridors (construction effects, use, and maintenance) on the addition of sediment in lakes, estuaries, and ocean outfalls. The tendency for contaminants to adsorb sediment particles is of concern in this area because the fate of contaminants is tied to the fate of the sediment in receiving systems. Empirical and modeling information is available on sediment movement, but good predictive models that consider runoff/storm relationships, particularly storm scour and redeposition, are unavailable.

Finally, there is a need to determine the runoff and receiving water impact associated with physical stressors to biota acting alone or together. This need can be met if mechanisms and processes of physical alteration in receiving waters are well described and connected to specific effects and actual impact on stream biota by clear cause and effect relationships.

**Needs in Chemical Analysis and Assessment**

Chemical effects in receiving waters range from alteration of reaction rates and equilibrium relationships through contaminant presence and concentration, to general water quality alteration. Although the chemical characterization of urban and highway runoff has been the focus of numerous studies (e.g., The National Urban Runoff Program and NCHRP 25-20), both short-term and long-term variability is poorly understood in "exposure scenarios" of importance to receiving water biota. These exposure scenarios include the estimation of water column concentration of contaminants due to source characteristics or solubilization and resuspension of contaminants deposited in earlier events, time-related change in contaminant levels during or following events, and long-term conditions that may affect contaminant degradation or reactivity.

Water quality regulations have been in effect for approximately 30 years. As a result, much is known about the effects of continuous discharges on the water quality of receiving systems. Not as much is known about the episodic runoff that is typical of transportation corridors. An area that has not received much attention is the change in reaction rates and equilibrium relationships for contaminants during runoff events. For example, it has been well documented that stormwater runoff results in low conductivity, low hardness, and reduced pH conditions; however, the effect of transient changes on the solubility and reactivity of chemical contaminants has not been well documented. When combined with the different flushing times of transportation corridors and the variability in contaminant availability, the potential exists for damaging effects in receiving waters.

The low conductivity, low hardness, and reduced pH conditions associated with storm-related runoff corresponds with a period when the contribution to contaminant loading from atmospheric sources may be very important. This is particularly true for highways that collect and intercept stormwater flows. Although there is a growing body of data on atmospheric contribution to nutrient and some contaminant loading, there is a clear need for research to identify and quantify atmospheric contaminant sources, especially those associated with highways where the source of particulates is in vehicles or roadbed construction materials. Snowmelt is another atmospheric source of contamination that can affect water quality. Snow can act as a storage compartment in some watersheds, but it can also add contaminants (e.g., road de-icing salt) to watersheds with special runoff characteristics. There is a need for research to define loading and dynamics of contaminants associated with atmospheric input.

In many respects, it is simply not known how to adequately express water quality conditions associated with runoff from nonpoint sources, including highways when quality is determined by specific regulatory goals that are often specific to the effect of contaminants on organisms or the condition or state of ecosystems. We can identify chemical changes in runoff, but it is difficult to translate those changes in concentrations or conditions to an evaluation of water quality. Because water quality is defined in terms of a specific goal (e.g., physical, chemical, and biological integrity), it may be argued that water quality characterization that is based on continuous-flow effluents or long-term ambient conditions is not appropriate for runoff from transportation corridors, even when controlled through detention facilities. To address this issue it is necessary to better integrate chemical analysis with physical and biological analyses, and develop improved tools for interpreting chemical characteristics in light of physical conditions and biological or ecological impact.

**Needs in Biological and Ecological Analysis and Assessments**

Biological effects can be divided into those with public health ramifications and those that are environmental/ecological. Although methods of pathogen determination are continuously improving, there are still research needs that must be addressed when considering the pathogenicity of runoff from various sources and how runoff may lead to public health hazards (e.g., *Pfisteria*). Research to assess the basis for and the effectiveness of disinfection under runoff conditions is needed. Because it is possible that disinfection would be affected by particles, research is needed to assess the effect of particles and particle characteristics on pathogens and disinfection. This relates to a better understanding of physical and sediment dynamics in receiving systems. Although disinfection will seldom be applied to highway runoff, the presence of sanitary sewer overflows or combined sewer overflows in drainage ways from transportation corridors may create a convergence of this issue with highway runoff control.

Environmental/ecological effects can generally be categorized based on how and where those effects are measured. Effect measurement following standard methods with a defined experimental control are typical of laboratory-based toxicity testing. Effect measurement following accepted methods, with no experimental control (rather the use of reference areas), are typical of field-based biosurveys and bioassessments. A general statement about biological/ecological effects associated with runoff is that the science is young, and the field is virtually unexplored when applications are made to episodic runoff conditions.

In toxicity testing there are standard methods available to measure the effects of an organism's continuous exposure to contaminants; however, there are no accepted standardized procedures for runoff toxicity assessment. There has been little progress in defining the organisms and responses that should be measured by toxicity tests. The nature of runoff dynamics is divergent to two extremes. One demands that test systems respond to particular contaminants over an extremely short duration, whereas on the opposite extreme, test systems should be responsive to subtle effects of residuals in receiving waters. Although progress has been made in developing runoff toxicity testing procedures, there is much to be done. It is possible to develop testing procedures for contaminants, even mixtures of contaminants in laboratory testing, but laboratory-based tests are notoriously unreliable in predicting actual receiving water impact. Furthermore, impact in receiving waters may be associated with the condition of the physical habitat or the life stage of organisms present. It will be necessary to develop a comprehensive and coordinated toxicity monitoring and assessment program that better integrates the full range of factors that affect toxic effect of runoff in receiving waters.

Toxicity testing procedures, including the selection of specific responses from test species, must be improved. Improved toxicity testing would ensure that short-term, continuous-flow, and long-term conditions/characteristics affected by runoff would be tested consistently. These results could then be compared across watersheds and ecoregions. Consistent toxicity assessments will go far to source identification/segregation in impact assessments.

In field-based biosurveys or bioassessments the methods needed to collect and enumerate organisms are well defined. Basic design principles to guide sampling and analytical methods for collected data are often inapplicable to many runoff studies because single sources do not exist. Runoff variability and the mix of runoff with the receiving system can compromise sampling designs for bioassessments. Source-specific runoff effects in receiving waters must be separated from the effects produced by industrial effluents, domestic effluents, and nonstorm nonpoint pollution. Runoff studies should characterize the runoff separately from the characterization of the receiving system. It may take many years before comprehensive analyses and statistically reliable interpretations can be made from highly variable receiving water conditions.

Another important issue for biosurveys and bioassessments is the need for a reference area. The developing biocriteria program is founded on the availability of reference areas that will define receiving water characteristics, which support assessment of relative quality. The difficulty in this process is in identifying appropriate reference areas for human-dominated landscapes and specification of comparable reference conditions for runoff analyses. In many areas, all natural streams have been modified, and reference conditions are established based on conditions observed at high-quality sites that may be some distance away. These reference sites may not actually be natural because of past watershed manipulation, although they have not undergone the magnitude of change common in urban streams. One of the major and most-often asked research questions in assessing the effects of runoff from a wide range of sources on receiving waters is "What realistic 'quality' should be expected in a stream where the watershed is highly or completely modified?"

To address receiving water questions it is essential to improve the design procedures for runoff studies. Testing runoff assessment designs on a national level could help identify general design elements and site-specific needs. It will be necessary to develop new analytical procedures for biosurvey and bioassessment data that are specific for runoff analysis and possibly specific for transportation-related runoff. As in toxicity testing, both sampling and analysis procedures should reflect the importance of the transient conditions associated with runoff. Sampling and analysis procedures should account for the time scales common to an event and between events. These conditions could quantify receiving water impact.

The following should be considered as we review research needs for transportation:

- The behavior of runoff in rivers, lakes, and estuaries, specifically mixing zone definition and variability;
- The mass balance of transportation runoff and the variation of transportation-related contaminants in receiving systems;
- Interactions between sediment and the water column under dynamic conditions;
- The fate of pollutants or contaminants considering transport, temporary storage, and behavior through time as contaminants age and processes are affected by multiple events and changing input conditions;
- The development of testing techniques that effectively evaluate runoff and receiving system change under dynamic conditions (examples include toxicity testing procedures for short-term and intermittent exposures and toxicity analysis of long-term exposure that evaluates both water column and sediment-related responses to time-related increase in contaminant concentration with storage and time-related response of test systems to variable conditions for single and multiple contaminants);
- The development of assessment techniques for single-event, multiple-event, and time-sequenced change in receiving systems;
- The identification/establishment of reference conditions to allow assessment against natural, more pristine systems, and against modified systems where maximum potential is the reference; and
- Development of testing and assessment procedures that are appropriate to different regions of the United States.

**Watershed Integration**

Watersheds provide a convenient basis for defining problem limits and the area contributing to a problem at a given location. Watershed integration would develop a means to integrate across physical, chemical, and biological/ecological factors to identify possible cause and effect couples. Watershed integration would also segregate transportation-related effects from other watershed influences. Watershed integration takes advantage of spatial definition, such as with a Geographic Information System (GIS), to better relate transportation corridors to receiving systems. For example, it is possible to use existing decision support systems such as the EPA BASINS to identify the location of continuous discharges and the determination of the impact of those discharges independent of any nonpoint or transportation-related runoff influence. Any assessment of runoff impact on receiving systems must be completed in the context of an integrated watershed analysis, which includes the effects of both continuous discharges and the wide range of nonpoint runoff sources. Possibly the most important issue in watershed integration is watershed location. Location issues include (1) geographic location, which may produce specific types of runoff problems like snowmelt, and (2) relative position within a watershed, which establishes an upstream area that may be related to pollutant or contaminant loading and the physical dynamics of runoff that are determined by concentration time and storm-flow hydrograph characteristics.

Channel change is another integrative measure in watersheds. Stream channels respond to changes in flow volume and sediment loading producing recognizable forms. Watershed change is known to have a corresponding effect on channels leading to bank erosion and head cutting. Although these processes are well understood and descriptions of channel form are well developed, effective predictive models of channel geomorphic response are lacking.
Groundwater may be considered a watershed-wide resource requiring specific attention in watershed integration. The interaction between runoff and groundwater, particularly vadose zone impacts produced by detention facilities, may be of significance in some watersheds.

The following research needs for transportation should be considered:

- Consolidation of regional runoff experience to support levels of generalization for the effects of multiple runoff sources in a watershed, including background conditions and runoff characteristics specific to watershed location;
- Development of techniques (e.g., GIS) that integrate all upstream influences in a site-specific analysis/modeling framework;
- Definition of standard measurement procedures for watershed integration;
- Development of methods to predict channel changes produced by runoff; and
- Stormwater–groundwater interactions.

Much literature exists to support watershed management. A redefinition of this literature in the context of ecosystem objectives and the use of analytical techniques such as GIS has revitalized research in watershed management. Implicit in newer approaches to watershed management is the effective integration of stormflow and runoff in more traditional watershed analysis procedures. A critical research need is the ongoing development and evaluation of techniques to integrate transportation-related runoff analysis in overall watershed management.

**Criteria and Standards**

An emphasis on continuous discharge has been developed through the regulation and management structure established by federal and state legislation. The implementation of water quality regulations should be modified to suit the episodic nature of transportation-related runoff. New criteria must be developed to (1) consider brief and episodic exposure; (2) effectively relate the physical habitat to chemical concentrations, thus providing a better correlation between the spectrums of causes with any observed effects in test organisms; and (3) integrate a range of physical, chemical, and biological issues to adequately protect ecosystems. Because a wide range of regulatory programs affect transportation, transportation agencies should aid in the development of this research and support comprehensive research needs assessments in this area.

To develop criteria and standards, it is imperative that the most appropriate measurements of effect are made and that the results of those measurements are presented in a way that supports regulation. This is true for any discharger or discharge type, but is particularly important for transportation, which is at the center of many environmental management issues. A major emphasis has recently been placed on the identification of indicators. An indicator may measure the state or condition of an ecosystem or an outcome of a management program that identifies success. Indicators are being identified and must be rigorously tested for both scientific accuracy and regulatory utility. A subelement of indicator development is the identification of indices. An index would be the foundation of indicator development; consolidating data from several metrics into a numerical value with a defined range describing desirable or undesirable conditions. The field of index development is fertile and can focus on individual physical, chemical, and biological/ecological categories of measurement or on integrative measures including two or more categories. There is a critical research need to develop a regulatory structure more appropriate to the episodic nature of runoff and identify indices and indicators specific to transportation-related runoff.

## Post-Workshop Committee Comments

The committee identified best management practices (BMP) research as a high priority for research activity. It was brought to the committee's attention that a pending project, NCHRP 25-20, addresses many of the BMP research needs recognized by this committee. Because the focus of NCHRP 25-20 is well described, the committee was reluctant to propose an additional project until the results of this research are known. In review of the project statement, the committee believes that additional resources may be necessary, beyond those provided by the proposed project budget. The potential cost savings from improved BMPs justifies additional expenditures in this important area of hydrologic and water quality control.

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RESEARCH NEEDS STATEMENTS

# Water Quality and Hydrology

### 1. HOW POLLUTED IS STORMWATER RUNOFF FROM TRANSPORTATION FACILITIES?

**Problem Statement**

The Clean Water Act, which was enacted in 1972 and amended in 1987 to include stormwater discharges, requires that states assess the condition of surface waters within their jurisdiction to determine whether they are "fishable and swimmable." Where water quality is not adequate to sustain these beneficial uses, these surface waters must be reported to the EPA as required by Section 303(d) of the Act [i.e., the 303(d) list]. A total maximum daily load (TMDL) must be developed for each of the listed segments for the constituents that are contributing to the impairment of the beneficial uses. The TMDL is the maximum pollutant load that can be assimilated by the waterbody without impairing its beneficial uses. There are more than 20,000 such impaired waterbodies identified nationally, comprising more than 300,000 miles of rivers and streams and more than 5 million acres of lakes.

Once a TMDL is developed for a surface waterbody, a waste load allocation (WLA) must be developed. The WLA specifies how much of a given pollutant can be contributed by each discharger to that waterbody. As TMDLs and WLAs are developed for the impaired segments, dischargers including transportation agencies may have to implement best management practices (BMPs) to reduce their contribution of the pollutant. However, transportation planners do not have accurate and current estimates of exactly how much pollution is from transportation facility runoff. In such a technical vacuum, regulators assume the worst and act accordingly, which can result in the unduly high costs of mitigation. Consequently, it is imperative that state departments of transportation (DOTs) and other transportation agencies have accurate knowledge of the quality of their discharge and the extent to which they contribute to the impairment of the listed segments. This information will allow them to submit scientifically valid input as stakeholders in the TMDL process. This type of data has not been compiled and analyzed since a study conducted by Driscoll et al. (1990), which precedes the widespread monitoring that has occurred over the last 10 years in response to National Pollutant Discharge Elimination System (NPDES) permit requirements and lawsuits by environmental groups.

It is likely that the concentrations of trace elements in stormwater runoff are governed by site-specific conditions such as rainfall properties, soil types, facility type, the contribution of facility use, maintenance activities, and other quantifiable factors. Stormwater monitoring of transportation system runoff is currently being conducted in nearly every state in response to permit requirements, lawsuits, and as part of research programs. These data are highly dispersed. Some agencies, such as the California DOT, maintain a central repository for collected monitoring data. Other agencies, such as the Texas DOT, perform extensive monitoring but maintain no central repository of monitoring data being collected by individual district offices. Furthermore, many cities are being required to monitor runoff from streets as part of their NPDES permit requirements. Thus, a wealth of monitoring data are being acquired but not assimilated and evaluated in a consistent and useful manner.

The objective of this research is to establish a detailed characterization of the stormwater pollution contributions from transportation facilities in various geographic settings to

- Help establish which conditions are benign and not candidates for regulation; and
- Identify specific pollutant classes for mitigation in appropriate BMPs (help avoid the use of inadequate mitigation measures).

**Proposed Research**

Those conducting the proposed research will:

- Compile stormwater quality information collected by DOTs nationwide as part of NPDES permit requirements, research programs, and other transportation activities.
- Evaluate the data for accuracy/validity with respect to establishing consistent measurements from one data set to the next.
- Develop a database of this information, which would include monitoring data cross referenced to relevant characteristics of the contributing areas and storm events such as: type of transportation facility, average daily traffic/load, number of lanes/rails, type of drainage system, surrounding land use, traffic mix, facility maintenance activities, rainfall intensity, rainfall volume, and antecedent dry period. These data could be used to update the Federal Highway Runoff Pollutant Model (Driscoll Model).
- Conduct a detailed analysis of these data to determine the emission of pollutants as a function of transportation facility attributes. This should be performed in a manner that will enable determination of loads for TMDL assessments and accurately determine expected quality of highway runoff (such as mean event concentrations) from a wide geographical cross section of sites based on the factors named previously.
- Identify gaps in data and develop a plan of action for additional monitoring and research.

TMDL requirements are currently being developed in every state. Outdated and inconsistent data are often used to estimate highway runoff quality. Many of these data were collected before lead was eliminated from gasoline. Using these data to generate TMDL requirements could result in

- Imposing on the facility owner (such as a DOT) excessive and unjustified requirements for the design and implementation of BMPs for new and existing transportation systems
- Cause the facility owner to use inadequate or incorrect BMPs for the predominant types of pollutants.

Therefore, there is an urgent need to assimilate and evaluate monitoring data and to better characterize the stormwater runoff quality.

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**Cost:** $500,000
**Duration:** 36 months

### 2. WATERSHED ASSESSMENT AND MITIGATION STRATEGIES FOR TRANSPORTATION SYSTEMS—PHASE I: SYNTHESIS AND METHODS ANALYSIS

**Problem Statement**

The transportation community generally regulates impacts by analyzing the impacts, negotiating mitigation, and securing permits on a project-by-project basis. This piecemeal approach is not only inefficient, but results in less cost-effective mitigation strategies. Some states are currently supporting efforts to assess surface water quality, groundwater quality, flooding, wetland protection, and stream bank/shoreline erosion within a watershed/ecosystem framework. However, these efforts are specific to the local/regional conditions of those states.

In the transportation community, there is an interest in developing a watershed model approach that considers the various ecological regions across the nation to assess the water quality and hydrologic impacts relative to planning, designing, constructing, maintaining, and operating transportation systems. It will be necessary to determine if the watershed framework is the more efficient and effective method for determining the most cost-effective mitigation.

Alternative methods for determining the impacts of securing the permits for transportation improvements are needed to streamline project delivery and to mitigate the associated environmental impacts in a cost-effective manner. Regulatory agencies are interested in partnering with transportation agencies in this effort.

**Proposed Research**

Determine how to integrate environmental issues into a watershed-planning framework specific to identifying the most cost-effective mitigation strategies for addressing transportation-related impacts to water quality and hydrology. Those conducting the proposed research will:

- Assess and report on current federal and state watershed regulations and identify regulatory hurdles in current watershed approaches.
- Poll all state DOTs and other surface transportation sectors and report on regulatory practices relative to transportation—are projects being regulated on a project-by-project basis or a watershed basis?
- Gather, assess, and report on current regulatory and transportation community watershed assessment practices and assess the effectiveness of these practices.
- Gather, assess, and report on available tools and methods in developing a watershed model framework for the surface transportation sector.
- Identify and report on the information needs for developing a watershed model framework for transportation corridors.

Develop a model watershed framework that could be comprised of connecting a system of models that:

- Takes into account regional differences in terms of hydrologic conditions, geomorphology, sensitive surface water and groundwater resources, and other environmental considerations.
- Takes into account the various transportation corridors and modes that currently exist within a watershed and can effectively assess the environmental impacts that could be associated with existing and future transportation improvements within that watershed.
- Evaluates the water quality and hydrologic impacts of transportation improvements on the watershed at differing scales.
- Identifies cost-effective mitigation strategies relative to the impacts resulting from transportation improvements.

Finally, develop a guidebook describing the decision support tree, information needs and inputs, and step-by-step procedures needed to conduct an analysis using the model watershed framework.

**Cost:** $500,000
**Duration:** 36 months

### 3. Watershed Assessment and Mitigation Strategies for Transportation Systems—Phase II: Protocols and Implementation

**Problem Statement**

Transportation project delivery is often impeded by regulatory requirements for the mitigation of water quality, hydrology, and habitat impacts within or adjacent to the transportation system right-of-way (in-ROW mitigation). In many cases this can be problematic or impossible because of site-specific constraints such as a lack of available land, presence of protected natural resources, unstable slopes, shallow water tables, excessive costs, and marginal environmental benefits. Additionally, in-ROW mitigation rarely addresses the most critical needs of the watershed or local priorities. Many states are currently supporting projects that are assessing surface water quality, groundwater quality, floodplain impacts, wetland protection, and streambank/shoreline erosion within a watershed/ecosystem basis. Transportation systems could potentially use the flexibility that watershed-based mitigation provides to reduce project costs, maximize environmental benefits, and address multiple ecological needs and functions.

Under the Clean Water Act, many transportation systems and all municipalities with populations greater than 100,000 are subject to NPDES stormwater permit provisions. In 2003, these federal requirements will be expanded to smaller municipalities with populations of more than 10,000. Other regulatory mechanisms including the Endangered Species Act, Coastal Zone Management, and local government regulations may require transportation agencies to extensively mitigate its project impacts. Transportation agencies may be inequitably burdened with mitigation costs relative to other land uses in many watersheds. New approaches and flexibility for mitigation are immediately needed if transportation systems are to improve project delivery and maximize the benefits of its environmental investments.

**Proposed Research**

Pilot watershed assessments will be conducted using the methods compiled in the Phase I proposal. Protocols for establishing critical needs and local priorities will be developed in Phase

II. Rationale for watershed-based mitigation versus site-specific mitigation will be developed from a cumulative effects perspective and will be closely linked to habitat suitability and loss of function from impacted sites. Opportunities for mitigation banking, retrofits, offsite mitigation development, pollutant abatement trading, and BMP design and placement for mitigation will be identified for watershed-based mitigation implementation. Guidelines for planning and design for flow conveyance, peak flow attenuation, and pollutant load management (e.g., total maximum daily load assessments, NPDES requirements, and local water quality standards) will be developed. The monetary and ecological benefits of watershed-based mitigation such as improved project implementation, watershed management for environmental sustainability, and socioeconomics, will be identified and quantified where possible. Information from this research can be used in the development of National Environmental Policy Act of 1969 and other environmental documents to streamline transportation project and system permitting.

**Cost:** $360,000
**Duration:** 36 months

### 4. Robust Sampling Protocols and Measurement Methods for Monitoring Runoff Constituents from Transportation Corridors

**Problem Statement**
Over the past few years, research in the constituents of transportation runoff including, sediments, trace elements, organic chemicals, and bacteria indicate that methods used for sample collection, processing, and analysis may affect the reliability and defensibility of data. Data sets may not be comparable unless it can be demonstrated that the different methods used to collect data from different studies produce equivalent results. When methods are properly documented, the data collected can be explained and related to other data sets in a quantitative manner. This information includes documentation of sample collection, processing, shipping, and analysis methods with respect to commonly accepted sample-handling protocols.

Sample integrity depends on proper and timely sample-handling methods for monitoring most constituents of concern. The effects caused by differences in handling methods can overshadow the real deviations caused by the explanatory variables. Upon collection, a sample almost instantly starts to undergo biological, chemical, and physical changes. Research has shown that sampling equipment may contribute, absorb, or react with runoff constituents in the timescale necessary for sample collection. Quality of the data depends on minimizing and documenting these changes. Adverse changes in samples can be minimized in a variety of ways, including use of standard processing materials of known composition and purity, precleaning sampling materials, chilling samples, the addition of preservatives, controlling and documenting sample-holding times, and the use of appropriate and defensible analytical methods. For example, the U.S. Geological Survey (Technical Memo 2001.3) has identified problems with Total Suspended Sediment measurement methods. Legal requirements for sample handling may include chain-of-custody documentation and analysis by certified analytical laboratories.

Methods used to collect, process, and analyze water quality data affect the quality, defensibility, and cost of the data collected. Therefore, a careful description of robust sampling protocols is necessary to ensure that current investments in data collection will generate accurate and useful data. Documentation of sufficient quality-assurance and quality-control information to establish the quality and uncertainty in the data and interpretations also are needed to determine the comparability and utility of data sets for intended uses. Water quality data that are documented to be meaningful, representative, complete, precise, accurate, comparable, repeatable, and admissible as legal evidence will meet the scientific, engineering, and regulatory needs of transportation agencies.

**Proposed Research**

Development of water quality monitoring standards that are applicable to the transportation community may appear to be a complex requirement, but similar standards are being developed within the more general water resources research community. The transportation community may benefit by adopting or adapting existing standards and by participation in wider efforts toward the development of available and comparable electronic data sets to document methods and results. Examples of existing initiatives to develop national data standards and information distribution systems include the development of:

- A model quality-assurance system, including detailed quality assurance/quality control protocols necessary to produce defensible data needed to meet requirements of the EPA.
- Protocols necessary for collection, processing, and analysis of environmental samples by the EPA, U.S. Geological Survey, National Water-Quality Monitoring Council, and other organizations.
- National documentation standards and performance-based measurement systems to maximize the availability, quality, and comparability of water resources data by the National Water-Quality Monitoring Council and other organizations.

The thrust of this research effort would be to identify, compile, and document existing water quality monitoring protocols and to assess their potential applicability for transportation research studies. This output would need to address the types of contaminants identified in transportation corridor water flows, as well as the nonroutine nature of the flows. The objective of this research is to develop a report/database that catalogs, evaluates, and rates existing sampling protocols for adoption by transportation agencies. This report/database will evaluate and rate available protocols by criteria such as reproducibility, accuracy, precision, defensibility, ease of use (in the field and/or in the laboratory), and cost-effectiveness. The final products should include a web page or other computer-based product that provides links to protocols that are available on the Internet.

**Cost:** $300,000
**Duration:** 24 months

## 5. Impacts of Transportation Best Management Practices on Groundwater Quality

**Problem Statement**

The ultimate fate of some treated transportation stormwater runoff from BMPs is groundwater. Groundwater is a precious resource. If groundwater quality has become degraded from transportation BMP stormwater runoff, the opportunities for the improvement of its water quality is extremely costly. Many beneficial uses of groundwater rely on high levels of water quality, which must be protected.

BMPs of concern that could contribute to the degradation of groundwater quality include infiltration BMPs, swales, detention basins, and wetlands.

Many state water pollution control regulatory agencies have nondegradation policies regarding groundwater quality. State DOTs need to know the potential extent and magnitude of groundwater quality degradation impacts from transportation BMPs.

**Proposed Research**

The objective of the proposed research is to provide state DOTs with a procedure to estimate the potential extent and magnitude of groundwater quality degradation from transportation BMPs.

The research project should include procedures to identify and evaluate current and potential uses of groundwater and water quality requirements that could be affected by transportation BMPs. The direction and flow movement in groundwater aquifers needs to be identified. Any pollutant plumes in aquifers must be evaluated, including direction of flow and concentrations. Treated stormwater quality from transportation BMPs that could infiltrate to groundwater should be identified in terms of flows, constituents, and concentrations. Soil characteristics between the BMPs and the groundwater must be described. The distance between BMP invert and the maximum groundwater elevation must be determined, as well as the rate of flow downward to the groundwater. The fate and transport of stormwater constituents from BMPs must be determined as the constituents move through the soil mantle and ultimately move through groundwater. Procedures should be developed to evaluate the extent and magnitude of any potential groundwater quality degradation from possible transportation BMPs.

**Cost:** $320,000
**Duration:** 30 months

### 6. Rapid Ecological Assessment to Predict or Model Measured Aquatic Ecological Effects of Transportation Corridors

**Problem Statement**

To more realistically characterize the environmental impact of transportation corridors there is the need for improved ecological assessment tools. Rather than using chemical parameters as surrogates for impact, or depending on toxicity testing that has limited capacity for extrapolation to ecological effects, improved tools that effectively assess the specific effects of transportation corridor runoff must be identified. Furthermore, improved ecological assessment tools can provide valuable information, contributing to the design of the transportation corridor. For example, these tools can be used to evaluate the effectiveness of BMPs to control pollutants generated in the corridor, thereby providing important information for environmental studies and permitting. Such assessment tools must respond to runoff variability and effectively differentiate transportation corridor effects from other watershed contributors to any observed ecological impact.

Evaluation of the causes of environmental degradation and loss of ecosystem integrity from transportation corridor construction and operations is needed to address both what is and what is not ecologically significant. Tools are also needed to evaluate the specific ecological effects of transportation corridors.

**Proposed Research**

The proposed research would include

1. A literature review to identify ecological assessment tools suitable for transportation corridor impact assessment, including tools that respond to discrete events and cumulative effects.
2. A pilot field study to evaluate the most promising tools identified in the literature review.
3. Development of reference ecological criteria based on tool application.
4. Development of a guidance document to assist DOTs in negotiation with resource and regulatory agencies.

**Cost:** $400,000
**Duration:** 36 months

## 7. Alternative Methods of Regulating Emissions and Discharges from Transportation Corridors

### Problem Statement

Transportation corridors present a complex and possibly unique regulatory situation. In an era of watershed-based management, transportation corridors typically extend across numerous watersheds and by their construction modify flow patterns in and between watersheds. Transportation corridors are a major, engineered feature in watersheds and have already been designed to meet stringent safety and environmental criteria (e.g., runoff control and hydrologic integrity). Transportation corridors can often present the opportunity to help solve watershed issues, because transportation corridors may divide watersheds into discrete units and have an inherent and robust engineering design. Transportation systems are often primary targets for regulatory action. Transportation corridors present sources of emissions and discharges, so that regulation is often needed to ensure that environmental quality is maintained. Unfortunately, methods of control commonly used to manage emissions and discharges do not address the linear character of corridors, the limited availability of rights-of-way, the potential of event-specific sources (e.g., spills), or the differences in environmental risk associated with use intensity and timing.

There are a number of strategies that have been applied to environmental regulation including emission and discharge trading systems and mitigation or other banking strategies. Each of these strategies requires new approaches to regulation and an altered relationship between transportation, resource, and regulatory agencies.

The specific characteristics of transportation corridor emissions and discharges and the clear need to sustain transportation infrastructure while minimizing environmental effect, shows a clear need for alternative regulatory mechanisms that would efficiently and effectively meet the public policy needs for environmental protection and transportation improvements. Transportation corridors provide an ideal opportunity to develop new management partnerships, some with trans-watershed integration.

There is an increasing emphasis on full accounting of emission and discharge sources in environmental regulation. Even though transportation corridors are pervasive in every state and community, transportation may actually be a small contributor to overall watershed change. Unfortunately, there is little opportunity for alternative management because of fixed and rigidly interpreted methods of regulation. For continued maintenance and improvement of needed transportation corridors, it is essential that alternative regulatory methods be identified immediately to promote the dual goals of efficient transportation and environmental protection achieved through new partnerships among watershed stakeholders.

**Proposed Research**
Those conducting the proposed research will

1. Identify opportunities for a change in regulatory system approach at the national, state, and local levels.
2. Develop a set of model regulations/ordinances, including trade-offs of control measures, reverification systems, and costs.
3. Complete a demonstration program.

The products of the proposed research are intended to be both guidance documents and documented approaches to multipartner integration in environmental protection. It is anticipated that the research effort will include a demonstration program to identify partners and provide new approaches to achieve environmental protection.

**Cost:** $400,000
**Duration:** 36 months

### 8. Development of Effective Protocols for Designing, Restoring, and Monitoring Stable Stream Channels

**Problem Statement**
Local, state, and federal transportation engineers encounter increasing difficulty in designing and maintaining transportation stream crossings. Typical problems encountered include how to stabilize degraded stream channels within the transportation right-of-way and how to design stable stream relocations that function within the overall morphology of the stream system. There are many different types of bank stabilization techniques that are available to the transportation engineer. These may include traditional techniques such as riprap armor, dikes or training structures, or some of the new techniques such as bendway weirs and bioengineering measures that are gaining popularity throughout the country. The suitability and effectiveness of a given bank stabilization technique are a function of the inherent properties of that technique and in the physical characteristics of the proposed work site. However, there is almost no guidance available for establishing the suitability of a particular technique for a particular site condition.

To establish effective guidance, long-term, comprehensive monitoring of completed bank stabilization projects at transportation stream crossings is essential. The performance of structures has generally been reported in an anecdotal manner based on observations over a short time period (1 to 2 years) and without any supporting field data. This is particularly true of some of the new and supposedly low-cost techniques that have been implemented in the past few years. The design of inexpensive bank protection measures can, in some cases, be false economy. There is a difference between cheap solutions and cost-effective ones; however, without a comprehensive monitoring program, it is often impossible to distinguish between the two.

An essential component of any bank stabilization project is a detailed geomorphic assessment of the stream system to identify the processes and causes of instability. That analysis may lead to the conclusion that appropriate alternative solutions may involve more than site-specific bank stabilization at the transportation stream crossing. Many bank stabilization projects have failed as a result of focusing too narrowly on the local processes and ignoring the large-scale instability that exists within the stream system. The designer must also be aware of other factors that may be peripheral to traditional engineering, but that are essential for a successful project. Consequently, the design team must integrate traditional engineering with environmental concerns such as stream biota impacts, wetland impacts, riparian and aquatic habitat quality, fish passage, and geomorphic impacts.

Transportation engineers must cope with sporadic, vague, and sometimes conflicting criteria and objectives for developing stream stabilization and relocation designs. Building on the products of NCHRP 24-19, transportation engineers need comprehensive and quantitative guidelines for selecting design criteria, methodologies, and specific practices.

**Proposed Research**

Assess the effectiveness of crossing and stream location designs and approaches using current fluvial geomorphological and engineering concepts and techniques. Research will include an evaluation of different approaches to stream classification, condition assessment, and channel relocation and restoration. The research will specifically evaluate a natural stability approach to stream channel design and streambank stabilization techniques. In partnership with stakeholders (U.S. Army Corps of Engineers, EPA, National Resources Conservation Service, and U.S. Forest Service) the primary result from the research program would be a design guidance manual that would provide:

1. A description of geomorphic channel processes and erosion failure mechanisms,
2. A discussion of regional issues,
3. More specific design guidance for stabilization measures and tolerance levels than are being developed in NCHRP 24-19, and
4. Simplified criteria for long-term monitoring and reporting to determine a national baseline.

If gaps are found in the information needed to complete the design manual, problem statements will be generated to serve in obtaining the missing information.

**Cost:** \$350,000
**Duration:** 30 months

### 9. Hydraulic Modifications to Achieve Watershed Total Maximum Daily Loads

**Problem Statement**

The transportation community is faced with a need to mitigate pollutant loadings from existing facilities to achieve watershed TMDLs. The mitigation need is made more acute as the land use around transportation facilities competes for a finite amount of allowable pollutant load. Existing transportation infrastructure includes extensive hydraulic facilities, which may be suitable for retrofit to provide such water quality benefits. Examples would include catch basin/inlet modifications, detention pond retrofit to embankments and/or outlet works, riser structures added to culvert/embankment systems, and the fostering of pipe storage in storm drains. The project is oriented to these and other possibilities. Transportation administrators are under pressure to address water quality concerns, some of which are driven by TMDL litigation. Reactive solutions can be expensive and unwarranted even though they can relieve short-term pressure. There are no coordinated programs to address how the existing infrastructure can be modified to benefit water quality. This problem is critical as the TMDL process moves forward, and agencies are spending money for TMDL implementation but do not have focused direction with respect to exploiting existing infrastructure or meaningful partnering.

The mitigation of the adverse water quality of highway runoff is a modern need. Existing infrastructure addresses getting rid of water and minimizing the spread of water in the gutters. This infrastructure offers several possibilities for retrofits to enable water quality mitigation. Focusing on what can be done with what we have is an immediate need that can address TMDL implementation in a cost-effective manner.

**Proposed Research**

The proposed research includes the following activities:

1. Identify any of the elements of existing hydraulic facilities that may be modified or enhanced to provide water quality benefits;
2. Review operation and design principles that can enable feasible and cost-effective modifications—hard design and/or management change;
3. Find and evaluate existing retrofits;
4. Install promising prototypes for evaluation through an annual monitoring cycle;
5. Generate implementation guidance for the retrofit of hydraulic facilities; and
6. Identify watershed partners that will share investment in modifications.

**Cost:** $450,000
**Duration:** 30 months

# Wetlands, Wildlife, and Ecosystems

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RESOURCE PAPER

# Wetlands, Wildlife, and Ecosystems

Gary Evink, *Private Consultant*

Since the last Environmental Research Needs in Transportation Conference in 1996, a great deal of progress has been made in understanding the relationships of wetlands, wildlife, and ecosystems to transportation activities. This has resulted from the necessity to satisfy legal requirements related to the National Environmental Policy Act and various regulatory programs concerning the protection of wetlands, water quality, air quality, and endangered species. State transportation programs do not have the luxury of waiting on research programs when dealing with the aggressive work programs that have resulted from the Transportation Equity Act for the 21st Century (TEA-21).

Therefore, progressive states have taken the lead in developing and conducting environmental research to address the complex issues that develop in relation to potential impacts to natural resources during transportation planning, development, design, construction, and maintenance. States are using research and planning money provided under TEA-21, along with state funds to conduct the needed research. The Federal Highway Administration (FHWA) has also provided funding to advance research that addresses national information needs. The strong environmental policy of the FHWA states that environmental research will play an important role in leading the country toward an environmentally sound transportation program. A perspective of enhancement beyond the required action has been suggested to the states by the FHWA.

The understanding of how wetlands, wildlife, and ecosystems contribute to our quality of life and our basic environmental needs to sustain life on this planet has also increased since the last research conference. This has brought additional attention to the need to more comprehensively address related issues in the transportation programs. More public and conservation group interest in seeing these issues addressed has resulted in transportation agency actions including some of the needed research.

One very positive aspect is that the sharing of research information has improved since the last conference. As the research is being conducted, programs have been developed to better share this research information. Research information has been shared through the publication of research results by the state transportation agencies and the FHWA. In addition, state transportation websites have been developed to share this information.

Several major conferences on ecology and transportation have been conducted under FHWA leadership in cooperation with state transportation agencies, other governmental agencies, and nongovernmental organizations. Proceedings from the International Conference on Ecology and Transportation series detail the results of research being conducted by international agencies. In addition, the North Carolina State University Center for Transportation and the Environment has conducted teleconferences that have brought together experts to discuss topics related to wetlands, wildlife, and ecosystems that can be provided to a national audience. The Center has also developed databases in these three topical areas that can be used to access the results of research from around the world. Other transportation centers around the county have also begun initiatives to help address wetlands, wildlife, and ecosystem issues.

Nevertheless, state transportation agencies continue to struggle on a daily basis with wetland, wildlife, and ecosystem issues on their projects. The research has for the most part not reached the point where it adequately addresses the concerns about these resources. Although the impact of transportation on these resources is better understood, the means to adequately address these impacts are slower in coming.

Wetlands, wildlife, and ecosystem research needs continue to be similar to those expressed at the last conference. Adequate impact evaluation tools still need development and testing on transportation projects. Techniques to measure the quality of ecosystems and associated biota need to be developed and tested. The effectiveness of mitigation or compensation for impacts should be evaluated. Furthermore, the effectiveness of programmatic approaches in accomplishing environmental and regulatory goals, while showing great promise, still requires thorough evaluation.

The U.S. Army Corps of Engineers continues to slowly develop the Hydrogeomorphic Wetlands Analysis Techniques (HGM). It would be overly optimistic to expect individual models to be ready for use in the transportation program in the next 10 years because of the slow pace of development. Therefore, individual state transportation agencies have been forced to work out approaches for wetland evaluation. The reality of using HGM as a technique for evaluation of wetlands on transportation projects has not been adequately researched. The need for such a labor-intensive technique is being questioned by many state transportation agencies. Before the transportation industry invests additional dollars in this program, research is needed to determine the applicability and need for this technique for transportation.

The adequacy of existing methodologies for addressing wetland impacts needs to be evaluated because of the mitigation or compensation results generated by the collaborative efforts between the transportation agencies and resource agencies. The question remains: Are there existing techniques somewhere that are cost-effectively doing the job for environmental documentation and permitting? In most cases, mitigation is a given and the question is delineation for quantity rather than wetland quality. Mitigation is ongoing for high-quality wetlands. Mitigation for marginal wetlands is also evident.Therefore, the question ends up being how much mitigation is adequate, and is a more elaborate evaluation technique necessary to adequately address the legal requirements and regulatory intent of various federal, state, and local programs?

An evaluation tool that shows promise in all of the ecological areas (wetlands, wildlife, and ecosystems) is Geographic Information Systems (GIS). Research conducted over the past 5 years, including National Cooperative Highway Research efforts, has shown that for early planning, GIS can assist in identifying environmentally sound alternatives to avoid problematic projects during the project development and environmental review stage of the program. Further research to refine the applications of GIS is needed to advance this promising area of science. This research needs to be specific in nature so that applications to identify ecosystems and process species location information are developed that aid biologists and planners in identifying environmentally sensitive features for alternatives analysis. By identifying these features early in the planning process, they can be brought to the coordination process early enough to resolve many issues before corridor selection and project development.

States continue to provide wetland mitigation that is “unsuccessful” from a regulatory perspective because the research to document “how to” is still developing slowly. Each individual wetland and wetland type has particular features that are unique so that there are few universal answers other than soil, hydrology, and vegetation. Success has been in some wetland systems, whereas others, such as seagrass, continue to be problematic. Evaluation of techniques for improving the ecological success and increasing the cost-benefit of wetland mitigation was identified as a need at the last conference. Evaluation of constructed U.S. Department of Transportation wetland mitigation projects to develop recommendations for future actions was also suggested.

Research should look at existing information on the evaluation process that leads to the decision to provide creation, restoration, and/or enhancement as the mitigation action. The techniques used to accomplish mitigation actions also need to be studied to determine cost and ability to improve ecological success of mitigation efforts. Basic factors incorporated into the mitigation efforts need to be documented and their success/failure detailed. This needs to be accomplished for different wetland types in different areas of the country. Although some efforts to document mitigation success have been conducted, the specific information to help state transportation agencies improve their projects has been limited.

Because of the limited successes in satisfying regulatory requirements by "creating or restoring" wetlands, states have moved to other approaches for wetland mitigation—fee-based compensation, wetland banks, or programmatic approaches. Successes are becoming evident for this approach, but little research has been conducted to evaluate the effectiveness of these programs. Fee-compensation, wetland banks, and programmatic watershed approaches to wetland mitigation were suggested as research topics at the last conference, yet these still remain inadequately researched. These are very important areas if we are to reach streamlining of the wetland regulatory programs. Projects developed at the local, state, and private levels need to be evaluated with case studies of the mitigation alternatives used, reason for use, agencies and persons involved in the project, problems encountered, effectiveness of the mitigation action, and project costs. The information could be used to identify applications where these approaches to wetland mitigation are appropriate.

The interaction of transportation activities with wildlife and ecosystems was an emerging science during the last conference. The first International Conference on Wildlife Ecology and Transportation occurred in 1996. Since then, much has been learned through international cooperation to address the impacts of transportation on wildlife and ecosystems. Four international conferences have resulted in a more complete understanding of potential impacts to systems and biota. Currently, a synthesis study looking at wildlife and transportation is being conducted under the National Cooperative Highway Research Program. Although this synthesis will provide much information about these topics, the limited funding provided under the synthesis program will not allow for the level of documentation needed to completely understand the relationships. This effort was suggested at the last conference at a more adequate level of funding. The result is that additional efforts will be needed to bring the mass of information that has been generated in the past 10 years to press.

The FHWA and the American Association of State and Highway Transportation Officials sponsored a technology transfer effort that resulted in an interdisciplinary team visit of five European countries—Slovenia, Switzerland, Germany, France, and The Netherlands. The results of this effort will be published. The information will aid in identifying techniques for evaluation and mitigation of impacts to wildlife and ecosystems. Although Europe has moved forward in this area, they too are at the development stage in many areas. The complexities of the variety of wildlife and ecosystems encountered around the world are immense. Similar to wetlands, there are few standard techniques that apply to every situation. The larger synthesis effort proposed at the last conference would bring the international data together to identify areas that need additional research.

In many respects, the research needs in the area of wildlife and ecosystems are similar to those in wetlands simply because wetlands are an ecosystem. Analysis techniques for upland systems are needed. Many states have begun to use GIS for larger perspectives when dealing with major corridors through important landscapes. This landscape view provides one level of analysis, but because transportation projects are linear in nature, projects encounter many types of ecosystems within the landscape. This aspect of scale is becoming better understood in environmental analysis for transportation systems and projects. This has resulted in research at all levels of the landscape from microhabitats to international landscapes. It is encouraging to see interagency and nongovernmental activity in helping to understand these relationships.

Wildlife research on everything from reptiles and amphibians to grizzly bears is being studied in relation to transportation. Fragmentation, connectivity, and road density take on different levels of importance when looking at the spectrum of habitat needs for the wide variety of organisms (wildlife) encountered in transportation projects. Looking at the total spectrum of transportation modes, it would be hard to identify an organism or ecosystem that is not affected in some manner—especially with the global nature of air and water pollution. Therefore, no area of environmental science is excluded from the discussion presently taking place in relation to transportation. This has lead to the necessity of the international effort to share scientific information.

The lack of understanding about basic biological factors for many species in the scientific community has led state transportation agencies into basic biological studies of organisms and systems to develop the science to address impacts. This is especially true for rare species and their habitats. This has also confused the roles of various resource agencies to the point that many transportation agencies are providing funding to resource agencies to help resolve the complex nature of transportation issues. Preservation of wildlife and habitat has brought the transportation industry into the arena of land use and land management battles. Secondary and cumulative impacts often become larger issues than direct impacts in the wildlife and ecosystem deliberations with resource agencies.

The importance of public land use management to actions of transportation agencies on projects has never been more evident. If millions are to be spent on transportation features for connectivity, land management needs to be there in perpetuity to ensure continued wildlife populations. The multiple use philosophy in public land use management has lead to diminished ecosystem and wildlife resources that make necessary the measures taken for rarer and rarer biota.

There has been an inadequate motorist response to present motorist education activities (signs, public service activities, etc.) to reduce wildlife mortality. This has resulted in the need for costly structural solutions in areas where mere driver caution would do the job.

This is the framework in which modern transportation agencies are working to address the multitude of issues that develop in transportation planning and development. Sadly, they are not getting enough help quickly enough to prevent the possibility of costly mistakes because of a lack of research information about what is needed. This burden falls on all agencies and groups working in the natural resources areas.

The rate of growth worldwide has outpaced the wise planning needed to ensure the environmental balance necessary to sustain our natural ecosystems and wildlife in concert with our anthropogenic infrastructure. Unfortunately, the transportation industry is charged with increasing infrastructure under these circumstances. Therefore, transportation personnel often find themselves trying to address issues that go beyond merely providing adequate transportation infrastructure to meet expanding demand. Couple this with existing road densities and structures that are often incompatible with associated natural systems and the challenge to the transportation and environmental community becomes even more complex.

Many of the research needs identified for ecosystems and wildlife at the last conference remain. First, we have not moved toward an understanding of the ecosystem functions appropriate for assessing the impacts of transportation projects other than to say that they all need consideration. Research needs to be conducted to identify the methodologies to characterize the integrity of ecosystems and identify potential impacts. This research needs to consider all levels of species and ecosystems. To characterize the functions of a study ecosystem, standards must be established that characterize ecosystems at their highest level of sustainable functioning. This is especially problematic because natural ecosystems are constantly changing through the process of succession.Therefore, what is evaluated during project development is not what will be there at the end of the project life.To further complicate matters, the techniques need to be relatively inexpensive, of a level that can be carried out by a field biologist, rigorous enough to meet National Environmental Policy Act standards, and designed to consistently characterize a variety of ecosystems. Therefore, we have the same problems associated with HGM in finding the balance of science and implementation necessary to adequately do the job.

As proposed at the last conference, ecosystem level methodologies for corridor-wide assessments need to be researched. Some research has been going on at the state level, but an investigation of the effectiveness of these efforts at the national level has not taken place for either connectivity or the overall species and ecosystem mitigation experience. The successes and failures of this research need to be shared between federal and state agencies. States continue to build costly structures for wildlife connectivity, wildlife mortality reduction, and to increase motorist safety. However, the long-term research to determine the most cost-effective approaches has not taken place. Most efforts to date have been short-term monitoring to see if the target species are using the structures, but little consideration is given to factors that would improve future efforts. A synthesis targeting the effectiveness of state mitigation experiences needs to be conducted. This effort needs to look at such factors as connectivity; habitat replacement, enhancement, and/or preservation; operation and ecosystem management practices; effectiveness of designs; invasive plant species efforts; and the best use of existing environmental data.

The secondary and cumulative impacts of transportation on wetlands, wildlife, and ecosystems is an area in great need of research. Although the direct impacts may be more obvious, the secondary and cumulative impacts are more illusive. The hope is that cumulative impacts can be addressed at the system planning level and that secondary impacts can be addressed through land use planning at the local and state levels. The method of accomplishing this needs to be researched so that standard methodologies of analysis are developed to assist the transportation planner, biologist, engineer, and resource agency personnel in finding the best approach to providing transport, while protecting the wider ecological resources in an area.

Programmatic efforts at the state level for wildlife and ecosystems have developed that have the potential to address both direct and secondary/cumulative impacts. These include ecosystem-level banks and preservation efforts to more satisfactorily address transportation impacts. Because the regulatory perspective for wildlife and ecosystems (other than wetlands) are different, a separate effort to look at these actions is needed. The research needs to look at the environmental and economic cost-effectiveness of these efforts. Documentation of the process leading to the action, methodologies used to implement the action, relative success of the action, cost of the action, and recommendations on where and when this approach might be best needs to be researched. This research could help environmental streamlining for wildlife and ecosystem issues move forward.

The sheer magnitude of factors involved in the research effort needed for wetlands, wildlife, and ecosystems dictates an interdisciplinary, multi-agency approach to accomplishing this research. The problem has always been that individual employees of any of the agencies involved do not have the knowledge to address all of the ecological aspects of transportation actions. Therefore, the most successful efforts have been the result of this interdisciplinary, multi-agency approach. However, when the scientific community becomes involved, evaluation techniques should not be turned into scientific research that is incompatible with the needs of transportation agencies. One promising area of science that could help this situation is expert systems. Interdisciplinary groups of experts charged with developing realistic evaluation techniques could be used to address the needs identified here. Using computer sciences, these techniques would be programmed such that qualified personnel could more efficiently arrive at decisions that best address any given issue. In this manner, the most important factors needed would be identified for future research efforts, thereby refining the initial efforts in accuracy and efficiency. Expert systems are showing success in other areas of science and certainly need to be considered in relation to environmental analysis in transportation. A research project to evaluate the applicability of this approach to wetlands, wildlife, and ecosystem analysis in transportation needs to be conducted.

RESEARCH NEEDS STATEMENTS

# Wetlands, Wildlife, and Ecosystems

## 1. Mapping Linkage/Connectivity Across Landscape for Multiple Species and Siting of Mitigation and Conservation Measures

**Problem Statement**

Habitat loss and fragmentation are the two leading causes of wildlife loss and extirpation. Degraded watersheds and fragmented wildlife habitats have a lower capability to sustain wildlife populations and important ecological functions than intact and interconnected habitats of sufficient size. At the same time, state transportation agencies must identify areas to mitigate impacts to wetlands and other habitats, preferably on a multispecies basis, to comply with state and federal regulations. Maps and protocols are needed to identify and predict areas of likely transportation and wildlife interaction and locations for conservation areas and crossings. A national geographic information system (GIS) with associated databases and maps of broad and intermediate scale linkages and high-priority conservation areas would assist state transportation agencies in developing programmatic approaches, performing advance mitigation, and maintaining habitat connectivity. This would aid in streamlining the transportation development process and advancing stewardship objectives. The need for this information has become even more critical with the advent of congressionally identified high-priority corridors.

**Proposed Research**

Assess and describe existing habitat and high-priority conservation area mapping efforts, including landscape level linkages and wildlife habitat connectivity. Include existing linkage and connectivity mapping efforts such as those in Washington and Florida. Other informational databases and sources to be reviewed include state and USGS Gap Analysis Programs, Natural Heritage Program data, county and regional greenway and development plans, state and federal land management and restoration plans, TNC and NHP conservation priority areas, and non-governmental organization and university modeling and mapping efforts.

Identify critical habitat variables and existing protocols for modeling linkages based on best available data, including existing plans and maps, aerial photography, and remotely sensed data.

Show existing linkages and high-priority conservation areas that should be preserved. Identify lost and compromised linkages important for restoration.

Create a national, state-by-state map and database for reference by state transportation agencies in siting mitigation and conservation measures according to watershed, landscape, and connectivity needs. Ideally this would include land ownership information, development potential, and identification of land uses that would be compatible with continued/future functioning as an important linkage or conservation area. This information will provide a basis for fine-scale design and placement of wildlife crossings on a project basis to maximize their cost-effectiveness and value to wildlife.

**Cost:** $1 million
**Duration:** 3–5 years

## 2. Wildlife Habitat Linkage Area Structures

### Problem Statement
Over the last decade, natural resource agencies and transportation agencies have become increasingly aware of the effects that highway and railroad systems have on wildlife. Habitat loss and fragmentation are the two leading causes of wildlife loss and extirpation. Fragmented wildlife habitats have a lower capability to sustain wildlife populations than large, interconnected habitats. The cumulative effects of highways on wildlife have been serious habitat fragmentation, wildlife mortality, loss of habitat, avoidance of otherwise suitable habitat by wildlife, increases in human activities, and the use of rural lands that support wildlife. Much of this impact can be avoided or minimized by state-of-the-art wildlife crossings and other mitigation.

### Proposed Research
Two connected phases of research are proposed: the first addressing where wildlife crossings should be located at a fine scale based on wildlife behavior and movement patterns, terrain, habitat characteristics, and characteristics of the transportation corridor; and the second what types of structures are most effective for representative wildlife.

The following should be considered when addressing where wildlife crossings should be located for representative wildlife species:

- Address how movement patterns of representative species react to highways, wildlife crossings, and related infrastructures, and how topography, habitat character, and the transportation corridors affect wildlife reactions. Many aspects need clarification, including the effects of traffic noise, traffic volume, and traffic speed on wildlife behavior.
- Assess how terrain and habitat features enhance or detract from the use of wildlife crossings and associated linkage areas. What are the most effective terrain and habitat characteristics to identify when placing crossings and linkage zones for representative species and multiple species?

The following studies should be conducted to determine what types of structures are most effective for representative wildlife species:

- What types of wildlife crossing structures are best for representative species such as deer, elk, small mammals, reptiles, and amphibians?
- What are the best structures for multiple species?
- How effective are existing structures in promoting wildlife crossings?
- What are the most cost-effective designs?
- How can existing crossings such as bridges and culverts be modified to facilitate wildlife movement?
- What are design elements that generally enhance wildlife use of structures such as fencing, natural light, and opening size?

**Cost:** $1 million
**Duration:** 3–5 years

### 3. Evaluation of Wildlife Crossing Systems

**Problem Statement**

Existing roadways often interrupt wildlife passage from one area to another for breeding, feeding, or general individual movement. There is considerable potential for additional disruption to wildlife passage from planned roadway construction and highway improvements. Lack of suitable crossing opportunities for wildlife can lead to serious consequences to wildlife populations and has created a safety hazard for motorists.

Wildlife crossing systems allow animals to cross roadways with reduced hazard to wildlife and motorists. The development of wildlife crossing systems often takes into consideration the placement of fencing and vegetation to channel wildlife to crossings, the identification of appropriate locations where animals are believed to need to cross, and the type of crossing facility (culvert, underpass, overpass, at a grade crossing with dynamic warning signs for motorists). There is potentially a wide variety of wildlife crossing systems that could be installed. The problem lies in the type of systems that are most effective. Research is needed to determine the most efficient and cost-effective methods of providing safe crossings for various species of wildlife.

**Proposed Research**

Research should evaluate existing wildlife crossing systems to determine their effectiveness. Various system types should be compared with respect to wildlife. In evaluating system effectiveness, consideration needs to be given to whether the design properties of the structure or the structure location are related to the utilization of the structure. The result of this comparison should be correlated to wildlife populations and movement patterns. The cost of each type of system should be compared based on reduction in wildlife mortality, the number of wildlife species that are served, and the reduction in loss of personal property and human lives. Determining animal behavior and response to the crossing system, using such technology as infrared video, is a necessary component of this research. A product of this research needs to include suggested design criteria for effective wildlife crossing systems for selected wildlife species of concern.

**Cost:** $250,000–$300,000
**Duration:** 60 months (time needs to be long enough to monitor for natural succession and fluctuations in animal populations)

### 4. Wildlife and Highway Barriers: An Integrated Approach to the Impacts and Mitigation Options

**Problem Statement**

Highways create a multitude of impacts on wildlife movement across the landscape. Some of the highway impacts result from the structure of the roadway, location of the roadway, traffic volume, right-of-way (ROW) fencing, concrete dividers, and guardrails. Each of these has the potential to limit the permeability of the highway to wildlife as they attempt to move across the landscape. The structural barriers associated with highways include ROW fencing, concrete dividers, guardrails, noise barriers, retaining walls, and cutslopes. The impacts of these barriers vary depending on height, placement, and visual permeability. These impacts vary by species groups. For example, ROW fencing and many types of guardrails may have little impact on the movements of rodents and other small mammals and amphibians, but may pose serious restrictions of the movement of large mammals. Conversely, concrete barriers potentially block rodents, amphibians, and small mammals. Larger and higher concrete barriers may also pose serious restrictions to larger mammals, particularly those that cannot see over these barriers, or for animals unwilling to jump over them. Thus, barriers associated with highways pose potential impacts to a broad range of wildlife species. In combination, these barriers may pose significant threats to wildlife movements particularly when they occur in combinations along highways in important wildlife habitats. There is a need to better understand how various species respond to highway barriers in an integrated approach, which involves simultaneously measuring the impacts of ROW fencing, guardrails, and concrete barriers on multiple species groups.

**Proposed Research**

The proposed research would document the impacts of multiple barriers, including ROW fencing, guardrails, noise barriers, retaining walls, cutslopes, and concrete barriers on wildlife in a representative section(s) of Interstate highway in habitats where multiple species of interest are present. A minimum of two study sites would provide repeatability. Species present in study areas should include amphibians, small mammals, medium-size carnivores, ungulates, and large carnivores. The objective of the work is to document the permeability of the various barrier types on the movements of each species group, taking into account existing road design. Specific information would be collected for each barrier type on the movements of each species group within the study areas. The cumulative impacts of the multiple barriers on movement across the highway for each species group would also be documented to produce an understanding that the highway is or is not permeable to each species group. The reason for the lack of permeability would be documented as to the type of the problem barrier. To understand if animals are using existing structures such as underpasses to cross the highway instead of negotiating the barriers along the highway, it will be necessary to document the use of these structures within the study area for the same species being monitored in relation to the barriers. The product of the research will be a synthesis of the impacts of ROW fencing, guardrails, and concrete barriers on a wide range of species groups in representative areas of Interstate highways. By understanding the impacts on species groups, it will be possible to highlight the mitigation possibilities related to each species group for each barrier type. Some of the results may lead to further research to assess specific mitigation possibilities for certain barrier types in a repeatable approach. This synthesis will be of national value in determining impacts of such highway-associated barriers in environmental analyses and in the development of highway design standards. These data will also be useful in understanding the impacts of highways and associated barriers on the health of various wildlife populations and on wildlife linkage across the country at a landscape scale. An additional goal of this work is to make recommendations for amendments to the AASHTO *Green Book* on barrier application in ecologically important areas.

**Cost:** $250,000 per year for 3 years
**Duration:** 3 years

## 5. A Synthesis of Monitoring Effectiveness versus Cost of Project Mitigation

### Problem Statement

Many dollars are invested in transportation project design, so when that design negatively affects impacts ecosystems, mitigation of those impacts is factored into that design. The scientists within the state or federal regulatory region of the agencies typically design what appear to be solutions to mitigate for those negative impacts. Many states are researching and implementing mitigation designs that would be effective for the problem at hand, with very little information regarding their basic effectiveness and cost. It would be easy to define "reasonable" mitigation if that information was known. It is important that a post-construction, scientific analysis of the effectiveness of wildlife crossing structures and analysis of the success of wetland mitigation sites be conducted on a sample of like projects. The analysis results could be used to determine cost versus benefit to the resource. Very few dollars are spent to retrieve the most valuable information to be gained from the project—how well it functions. When that information is determined, it must be made available to the audience most likely to benefit, the individuals who seek mitigation alternatives.

### Proposed Research

The information should be compiled across a range of projects, with pre- and post-monitoring, along with their costs, to give a summary of existing information. It is also important to document monitoring design, monitoring period length, and the species monitored for each study to provide an overview of all previous work. Contact state departments of transportation (DOTs) to identify projects where money and time has been spent on pre- and post-construction monitoring. The research will be most valuable if data are available pre-construction, during construction, and post-construction. To compare apples to apples, a standard outline of information to be evaluated must be developed and completed for each project. The available information gathered for existing projects should be evaluated for its commonality, with identification of data gaps. Guidance would be developed on the appropriate information to collect during monitoring so that cost-effectiveness can be assessed. Information needs would vary between topical areas such as wetlands, stream restoration, and wildlife crossings. For wildlife crossings, it is proposed that information be gathered from each state that has wildlife crossings developed, and then evaluated to determine if the information is compatible for comparison to other projects. Identify projects of a similar nature that need post-construction evaluation and target those for follow-on individual research projects to add to the body of knowledge. For wetlands, evaluate the long-term viability of the mitigation project. Does the wetland function as designed and over how long of a period?

**Cost:** $300,000
**Duration:** 24–36 months

## 6. Effectively Maintaining Riparian Ecosystems Crossed by Transportation Facilities

### Problem Statement

Highway crossings can have a negative impact on stream and riparian ecosystems by creating barriers that inhibit the movement of fish, reptiles, and mammals, as well as fragmenting and destroying habitat. This fragmentation can result in the loss of important spawning areas, low water refuges, and travel corridors. Culverts are frequently seen as the most cost-effective structures for small stream crossings. However, in view of additional regulatory and resource management requirements, bridges may be more effective over the operational lifetime of the facility when project development times, costs, and construction schedules are considered.

**Proposed Research**
Compare the effectiveness of crossing structures, including corrugated metal pipes, concrete box structures, and bridges, on a variety of projects to establish:

- Development time,
- Construction cost,
- Maintenance requirements, and
- Ecological characteristics such as passage of fish, other aquatic organisms, and riparian-based wildlife.

This comparison will be done by:

- Completing a synthesis of existing research and data;
- Surveying several representative states, which will provide a depiction of regional considerations and a variety of indicator species; and
- Conducting interviews with resource and regulatory agencies to determine time frames and restrictions effecting future installations and current maintenance requirements.

The two products are to provide a comparison of crossings on comparable streams in terms of

- Project development schedule,
- Time for environmental reviews (NEPA, Section 404, ESE, etc.),
- Ecological effectiveness in fish passage and ecosystem integrity,
- Maintenance scheduling and costs, and
- Context-sensitive designs, which can be used nationally in a variety of riparian habitats.

This research will provide a better understanding of how to successfully design crossing structures to improve and enhance riparian habitat.

**Cost:** $300,000
**Duration:** 18 months

## 7. Methods for Assessing Transportation-Related Secondary and Cumulative Impacts to Wildlife Communities and Habitat

**Problem Statement**
Transportation projects are required by federal and state law to consider the secondary and cumulative impacts associated with a project. Several issues arise from this requirement. One is identifying the relationship among the transportation project, local land use plans and zoning,

timing of development in the area, and responsibility for the mitigation of adverse impacts. A second issue is the lack of suitable methodologies for quantitatively or qualitatively identifying secondary impacts and the magnitude of their cumulative effects.

The transportation agency is expected to mitigate secondary impacts associated with future development within the project area. However, there is no body of information that identifies the land use impacts and changes that are attributable to transportation projects. In situations where local land use planning encourages development, it is difficult to determine where the responsibility for mitigation lies. Transportation projects are often responsible for development that takes place after completion of a project, even though development of an area is often encouraged or predetermined through the actions of the local planning agency or through land use planning and zoning.

**Proposed Research**

The proposed research will use existing data (e.g., aerial photography, GIS, and comprehensive plans) that provides a history and chronology of changes around transportation projects and analyzes the relationship of this development to the project. The research will identify a number of transportation projects in several ecoregions for a variety of project sizes and complexities. The research will document the changes that take place within the area following completion of each of the projects. The data collected will include:

- Preproject conditions at the site,
- Land use,
- Wildlife population habitat types and condition,
- Water quality and quantity,
- Human population and infrastructure, and
- Postproject changes, planned land use (e.g., comprehensive plans), and zoning over time.

The project will then analyze the data and develop

- Methodology and guidance in identifying, qualifying, and quantifying secondary and cumulative impacts associated with a transportation project on ecosystems.
- Method and guidance to help identify responsibility for development or its control.

**Cost:** $250,000–$350,000
**Duration:** 24–36 months

## 8. Ecologically Sensitive Transportation Corridor Right-of-Way Management

**Problem Statement**

Highway rights-of-way (ROWs) include large areas of land throughout the country that have historically been managed by planting with non-native grasses, limited ornamental plantings, and implementation of an energy- and labor-intensive mowing regime. Goals that currently direct ROW management include safety considerations designed to prevent tree growth adjacent to the travel way for safety purposes. There are many problems associated with existing management practices. Herbicides are routinely used to eliminate vegetation from guiderails and other structures. Impacts to native and sometimes endangered or threatened wildlife, plants, and aquatic life may result from herbicide use. Current practices may result in the attraction of wildlife such as deer that increase the potential for deer–vehicle collisions resulting in human and wildlife injuries and mortality. Current practices encourage the spread of invasive plant species both linearly and laterally into adjacent native vegetation communities. Survival of nonnative plantings is reduced, as they are generally not adapted to the local soil and climatic conditions or hydrologic regime. Opportunities for expansion of existing adjacent native vegetation communities and wildlife habitat are lost by these practices. Maintenance of a wide, non-forested ROW in areas bordered by forest habitat may increase the effect of habitat fragmentation and affect the use of the adjacent forest by certain wildlife species.

**Proposed Research**

The goal of the proposed research is to develop an Ecologically Sensitive Right of Way Management Guidance Manual that provides for protection and enhancement of ecological resources and reduces maintenance costs. The manual should guide users to evaluate multiple management objectives, some of which may be mutually exclusive. The researcher should first identify and examine existing studies and manuals for habitat management in transportation facilities ROWs and, as applicable, other ROWs such as utility transmission corridors. Research on related topics such as habitat restoration and management and impacts of habitat fragmentation should be reviewed. A manual should then be developed for universal application that identifies the approach and alternate techniques for developing a ROW maintenance plan. The manual should identify how site-specific management goals will be identified. Potential sources of information regarding existing conditions should be listed. The management techniques identified should:

- Consider existing characteristics within the ROW, such as wetlands and stream corridors;
- Consider adjacent land uses and ecosystems (context-sensitive design);
- Encourage the establishment of native plants;
- Control invasive species;
- Avoid or minimize the use of herbicides, particularly in ecologically sensitive areas;
- Expand habitat for appropriate native species;
- Protect endangered and threatened species;
- Protect and improve surface water quality and hydrology;
- Discourage wildlife vehicle collisions;
- Facilitate safe wildlife movements;
- Provide for removal of accumulated trash; and
- Use GIS and/or other technologies to look at ROW management at an ecosystem level.

ROW management should also minimize labor and energy costs in the long term. Driver safety must also be addressed.

The approach for plan development should include identification of a multidisciplinary planning team. Team members may include natural resource management professionals, highway maintenance staff, highway department administrative staff, and resource protection agency personnel.

**Cost:** $200,000
**Duration:** 2 years

### 9. Evaluating and Improving Local Deer Density Reduction Countermeasures to Mitigate Deer–Vehicle Collisions

**Problem Statement**
Deer–vehicle collisions (DVCs) on U.S. roadways are a serious safety concern. DVCs cost consumers, businesses, and governments hundreds of millions of dollars annually. In addition to the 100 to 200 people killed and the several thousand people injured each year in these collisions, there are environmental consequences associated with the deaths of hundreds of thousands of deer.

Deer–vehicle crashes have secondary, negative influences on the driving public's attitudes towards wildlife, roadways, and the agencies that manage them. Direct costs to transportation and resource agencies are rising, notably in roadway management, law enforcement, carcass disposal, data management and communication with the driving public, trucking industry, and insurance industry. An established contributor to deer–vehicle crashes is local deer abundance. Replicated tests with documented outcomes of mitigation achieved through local deer herd reduction are essential and must begin now.

**Proposed Research**
In a selection of states, and across a gradient of ecological and transportation factors, this experimental research would test for correlations among areas of known deer abundance and established rates of DVCs. This study will take into account differences in traffic volumes, road densities, speed limits, usage patterns, adjacent land use, and the timing of crashes. It is believed that this approach will expose thresholds at which deer population density becomes a more or less overriding factor in the frequency of DVCs. Effectiveness of animal control efforts on crash mitigation is supported at the statewide scale from the experiences of several states.

Experimental and control areas will be selected based on the ability to select for critical dependent variables, as well as the ability to implement essential treatments and sustain them for several years. Baseline data will be secured before experimentation over a statistically meaningful period of up to several years. Treatments may consist of regulated hunting, sharp shooting, or other acceptable and measurable density management techniques. Follow-up treatments and data collection will be conducted over a 3-year experimental period. Final results will be published.

**Cost:** $1,000,000–$1,500,000
**Duration:** 24 months—statistical review;
4 to 6 years—replicated, experimental testing

### 10. Invasive Species and Transportation Facilities

**Problem Statement**
Many invasive species, particularly non-native plant species, are recognized threats to native plant and animal species, plant communities, biodiversity, and ecosystem function and balance. Invasive species are considered the second greatest threat to biodiversity. The construction and

maintenance of transportation systems have contributed to the spread of invasive plants, both through intentional maintenance practices and through inadvertent introduction/migration of these species along ROWs. Presidential Executive Order 13112 requires that all federally funded activities should develop programs to identify, control, and eradicate invasive plant species. To effectively accomplish the goals of the Executive Order, control measures that are both cost-effective and efficient for control of the species of concern need to be identified and/or developed for use on ROWs. The long-term effectiveness of these measures needs to be monitored.

**Proposed Research**
Research in this area will be regionalized to deal with species of concern in different parts of the country. Species of concern include, but are not limited to, purple loosestrife, phragmites, Japanese knotweed, black locust, garlic mustard, Russian thistle, kudzu, spotted knapweed, star thistle, and many other species. As a result, it would be anticipated that several regional research projects might be needed to allow state DOTs in different parts of the country to address this issue. Research could address control of these species in the ROW. Research to address mechanisms of dispersal for some species may also be needed to address control of future spread.

Control measures developed should be environmentally acceptable as well as efficient and cost-effective. This should include consideration of broader efforts of local, state, and federal agencies. Control measures using natural control mechanisms, which provide long-term control, should be a priority. Verifiable results should be a goal and mechanisms to minimize or eliminate recurrence should also be included in the solutions researched.

**Cost:** $100,000 (possible multiple projects regionally)
**Duration:** 2–3 years (to identify and measure effectiveness of control measures)

**Collaborative Research Needs Statements**

**11. Synthesis of Noise Effects on Wildlife and Development of Impact Assessment Guidelines, 317**

For full text, see Section 7 under Noise, 202

**12. Rapid Ecological Assessment to Predict or Model Measured Aquatic Ecological Effects of Transportation Corridors, 317**

For full text, see Section 6 under Water Quality and Hydrology, 296

**13. Ecosystem Impacts: Integrated Planning Strategies and Assessment Methods, 317**

For full text, see Section 11 under Sustainability, Including Climate Change: Cause and Effects, 239

APPENDIX

**Conference Attendees**

Alfedo Acoff, *Alabama Department of Transportation, Montgomery, Alabama*
Kevin Adams, *Kansas Department of Transportation, Topeka, Kansas*
Ken Adler, *U.S. Environmental Protection Agency, Washington, D.C.*
Kathy Ames, *Illinois Department of Transportation, Springfield, Illinois*
Katherine Andrus, *Air Transport Association, Washington, D.C.*
Bob Armstrong, *Federal Highway Administration, Washington, D.C.*
Steve Ashby, *U.S. Army Corps of Engineers, Vicksburg, Mississippi*
James Bach, *The Louis Berger Group, Inc., East Orange, New Jersey*
Michael Ball, *Transport Canada, Ottawa, Ontario, Canada*
Gibson Barbee, *Norfolk Southern Corporation, Roanoke, Virginia*
Richard Bechtold, *QSS Groups, Inc., Lanham, Maryland*
Ira Beckerman, *Pennsylvania Department of Transportation, Harrisburg, Pennsylvania*
James Bednar, *CH2M HILL, Dublin, Ohio*
Lisa Beever, *Charlotte County–Punta Gorda MPO, Punta Gorda, Florida*
Robert Bernhard, *Purdue University, West Lafayette, Indiana*
Jon Berry, *WRS Infrastructure & Environment, Inc., Tampa, Florida*
Susan Borinsky, *Federal Transit Adminstration, Washington, D.C.*
Frank Bracaglia, *Vanasse Hangen Brustlin, Watertown, Massachusetts*
Carol Braegelmann, *Federal Transit Administration, Washington, D.C.*
Marc Brenman, *U.S. Department of Transportation, Washington, D.C.*
Allyson Brooks, *State of Washington OAHP, Olympia, Washington*
Tracy Brown, *Michael Baker Jr., Inc., Coraopolis, Pennsylvania*
James Bryson, *Tennessee Department of Transportation, Nashville, Tennessee*
Melvin Burda, *Burlington Northern Santa Fe Railway, Fort Worth, Texas*
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Joe Darling, *New York State Department of Transportation, Albany, New York*
Elizabeth Deakin, *University of California, Berkeley, California*
Roy Deitchman, *Amtrak, Washington, D.C.*
Greg Dierkers, *Center for Clean Air Policy, Washington, D.C.*
Bruce Douglas, *Parsons Brinckerhoff, Herndon, Virginia*

Thomas Down, *National Center for Smart Growth, College Park, Maryland*
Micah Downing, *Wyle Laboratories, Inc., Arlington, Virginia*
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Andrew Edwards, *Federal Highway Administration, Atlanta, Georgia*
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David Fasser, *New York State Department of Transportation, Albany, New York*
Andy Fekete, *New Jersey Department of Transportation, Trenton, New Jersey*
Larry Finegold, *Finegold & Son, Consultants, Centerville, Ohio*
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David Greene, *Oak Ridge National Laboratory, Santa Ana, California*
Rob Greene, *URS Corporation, Knoxville, Tennessee*
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Brent Haglund, *Sand County Foundation, Madison, Wisconsin*
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Lori Kennedy, *Kisinger Campo & Assoc., Atlanta, Georgia*
Kenneth Kerri, *California State University, Sacramento, California*
Richard Killingsworth, *University of North Carolina, Chapel Hill, North Carolina*
Terry Klein, *SRI Foundation, Corrales, New Mexico*
Harvey Knauer, *Environmental Acoustics, Inc., Harrisburg, Pennsylvania*
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