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Environmental Research Needs in Transportation

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ENVIRONMENTAL RESEARCH NEEDS IN TRANSPORTATION

TRANSPORTATION RESEARCH BOARD
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INTRODUCTION

Protection of the natural and built environment is a primary and continuing responsibility of those agencies charged with the development, operation, and maintenance of the nation's transportation system. This responsibility is codified in requirements of the Clean Air Act, the Clean Water Act, the Intermodal Surface Transportation Efficiency Act, and the National Environmental Policy Act, among others.

Environmental stewardship requires policies and practices that are informed by accurate information on the complex relationship between the transportation system and the world around it. Such information can only be achieved by ongoing scientific research that addresses all relevant aspects of the environment. This Transportation Research Board Circular documents the second in a series of conferences held to identify and document the most critical transportation environmental research needs, as a guide to research agencies and programs. The first of these conferences was held in Denver, Colorado in 1991, and resulted in the TRB Circular 389, Environmental Research Needs in Transportation.

In November 1996, 140 environmental experts from around the country assembled for two and one-half days in the Transportation Research Board's Washington offices and worked collegially to identify research needs. Participants formed into thirteen work groups, each group representing a different environmental topic area. After identifying and prioritizing research needs, the groups drafted work statements and budgets for the top research needs. These research statements form the main body of this document, along with resource papers developed for each topic. Following are the thirteen topic areas:

- Aesthetics and Visual Quality
- Air Quality
- Cultural Resources
- Energy Conservation, Alternative Fuels, and Climate Change
- Environmental Review Process
- Hazardous Material Transport
- Hazardous Waste
- Noise
- Operations and Maintenance
- Social and Economic Impacts, Including Environmental Justice
- Water Quality and Hydrology
- Wetlands
- Wildlife and Ecosystems

Initially, there were twelve topic areas. The members of the Hazardous Waste work group decided their area needed to be split into two discrete topics, Hazardous Waste and Hazardous Material Transport, resulting in thirteen topics.

Conference Preparation

The success of this second effort to identify environmental transportation research needs is due to the 140 highly qualified people who took the time to meet for two and a half days of intensive work on the different topic areas. Their work was facilitated by careful advance preparation, as described below. Documentation of this preparation may be an aid to those planning future research needs conferences.

1. Conference Steering Committee

A steering committee was appointed, chaired by Thomas Weck, chair of the TRB Committee on Environmental Analysis. The membership of the steering committee included representatives from each of the sponsoring agencies- the Federal Highway Administration, North Carolina State University Center for Transportation and the Environment, American Association of State Highway and Transportation Officials, U.S. Environmental Protection Agency, National Association of Regional Councils / Association of Metropolitan Planning Organizations, and Surface Transportation Policy Project. This group took an active oversight role in all aspects of conference planning, and met on a bi-monthly basis during the year preceding the conference.

2. Abstracts of Environmental Research in Transportation, 1992 - 1995

The Center for Transportation and the Environment (CTE) prepared a report to document research conducted during the five-year period following publication of Circular 389. The purpose of the report was to guide development of new research statements by identifying recent accomplishments. CTE undertook two parallel tasks to prepare this report. First, they contacted both environmental and research division heads at each state department of transportation, national and international transportation organizations, and environmental interest groups to gather abstracts of recent research. Second, they searched

computerized databases, such as TRB's TRIS. The statements received from these tasks were sorted by topic area, and published in the final report. While supplies lasted, the report was provided, along with a copy of Circular 389, to each person who made a commitment to attend the conference.

3. Requests for Research Statements

Starting in December 1995, requests were made for brief, draft transportation environmental research needs statements. These requests were made of TRB committees with environmental interests, federal agencies, and of each state department of transportation, state environmental or natural resource agency, and person invited to attend the conference. The draft statements were turned over to Apogee Research, Inc. for editing and supplemental work. In total, approximately 600 statements were gathered prior to the 1996 conference.

4. Invited Participants

To assure a balance of professional skills, geography, and organizational interests, invitations to the conference were targeted. The invitation list included members of each state DOT environmental office, each state environmental agency, TRB environmental committees, universities and research facilities, private non-profit environmental agencies, and federal agencies (Advisory Council on Historic Preservation, Army Corps of Engineers, Bureau of Indian Affairs, FHWA, Fish and Wildlife Service, FTA, NASA, National Trust for Historic Preservation, and the Volpe Center). A strong effort was made to assure that each working group had from 8 - 12 members, with a balance of interests.

5. Background Papers

A background paper was prepared for each of the original twelve topic areas to stimulate thought and provide background and context for conference participants. The background papers were prepared by Louis Berger and Associates, and six were later amended or rewritten by the working groups. The twelve papers are included in this report at the beginning of each topic area. There is no paper provided for Hazardous Materials Transport, since that topic emerged during the conference.

6. Advance Materials

A document was prepared by Apogee Research, Inc. containing the 600 draft research needs statements received and the twelve resource papers. This was mailed to each pre-registered participant well in advance of the conference, and handed to each walk-in participant.

7. Facilitators

For each work group, a facilitator and co-facilitator were appointed in advance of the meeting. Facilitators were given the charge of assuring that their group identify at least five top research needs statements and draft a detailed, complete publishable statement for each. As well, the facilitator (or an appointed person from the group) was asked to make a ten-minute presentation of their work at the plenary session closing the conference.

On the evening before the conference, a training session was held for facilitators to go over conference goals and objectives and the process and schedule for the work groups.

8. Computer Resources

Each of the twelve meeting rooms was supplied with a PC computer, and, on a floppy disk, a copy of the draft preliminary research statements for the group meeting in that room. Photocopiers and computers were available in common areas outside the rooms.

FUTURE CONSIDERATIONS

The conference documented by this report focused in detail on research needs in thirteen discrete topic areas. Some larger, interrelated research issues were beyond the scope of the conference, but do need to be addressed. These include:

- The overall policy direction that will guide research initiatives;
- The relationships between the topic areas; and
- At what levels should resources be allocated among the topic areas.

Finally, it is expected that the research statements in this report will, in many cases, stimulate or give direction to future research. It would be most useful to know which topics are being undertaken, so that all may take advantage of the work performed and duplicative effort can be avoided. Those initiating such research are requested to inform the Transportation Research Board of their work, at the following address:

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2101 Constitution Avenue, N.W.
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AESTHETICS & VISUAL QUALITY

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BACKGROUND PAPER

Transportation facilities have a significant impact on the visual quality of the landscape, both natural and built, and the visual quality of the landscape has a significant impact on the transportation experience. If visual quality is an afterthought, rather than a primary consideration in the planning and design of transportation facilities, aesthetics are often seen as something that merely adds to the cost of a project. Community resistance to transportation projects can be directly traced back to a lack of sufficient concern for aesthetics and visual quality. When aesthetic and visual quality concerns are fully incorporated into the planning and design of transportation facilities, this results in projects that enhance rather than detract from quality of life in our communities.

Successful integration of aesthetic and visual quality concerns into planning and design requires continuity in the consideration of aesthetics throughout all aspects and stages of the project development process: from problem definition through planning, design, implementation, operations, and maintenance. Aesthetics should not be thought of as "add on" treatments to transportation facilities, rather they should be an integral part of the process and the product. Successful integration requires on-going public involvement, so that aesthetic strategies reflect and respond to the concerns, priorities, and preferences of the community. Successful integration requires a sensitivity to the context, the visual quality of the natural and man-made landscapes, and the scale, from a region down to a curb cut. Successful integration requires a basic understanding of how humans perceive and respond to visual qualities of the transportation system and the surrounding landscape.

These requirements apply to all types of transportation facilities, whether highways, transit, or local streets, and to the building of new facilities as well as the rehabilitation of existing facilities. Although growing attention is being given to aesthetics in highway planning and design, similar attention should be given to aesthetics in the planning and design of transit facilities and local streets. Many urban rail systems reflect significant attention to aesthetics in the design of stations and even vehicles, but concern with aesthetics in bus systems is noticeably lacking. Thanks to the New Urbanism movement, more attention is also being given to the design of local streets; the goal is to create streets that do not simply provide for the movement of vehicles but are also attractive to pedestrians and drivers alike. Highway rehabilitation projects often have dramatic impacts on visual quality (whether by necessity or by legal requirement) and merit the same attention to aesthetics as new highways. Rehabilitation projects may also offer the opportunity to fix past mistakes.

In evaluating the state-of-the-knowledge and the state-of-the-practice in the area of visual quality and aesthetics in transportation, five broad interrelated themes emerge. First, the process by which a transportation facility is planned, designed, and implemented and the degree to which visual quality and aesthetics are incorporated into the process significantly impact the success of the facility. Second, efforts to incorporate visual quality and aesthetics into planning and design must draw on a basic understanding of how humans perceive and respond to the physical environment. Third, the value of attention to visual quality and aesthetics in the planning and design of transportation facilities needs to be factored into analyses of costs and benefits. Fourth, a number of specific issues, such as the retention of trees and the design of traffic barriers, continue to challenge designers. Fifth, incorporating visual quality and aesthetics into the planning and design of transportation facilities requires innovations in communication and education.

Process

Experience has shown that an integrated project development process is essential to effectively addressing visual quality and aesthetic concerns. The project development process needs to be integrated in three ways. First, visual quality and aesthetic concerns must be considered in every stage of the process, from problem definition, through planning, design, implementation, and operations and maintenance, and throughout all activities within these stages. Second, the process must ensure continuity between the various stages, so that aesthetic problems or solutions developed at one stage continue to be addressed at subsequent stages. The process should not be entirely linear. Third, public participation needs to be integrated into the process throughout, to ensure that aesthetic solutions reflect the priorities and preferences of the community. Integrated, multidisciplinary planning and design teams should include engineers, planners, landscape architects, cultural specialists, and other relevant professionals, as well as community representatives.

A paramount issue in the development and construction of transportation facilities is the coordination of the design and planning processes with the communities in which these facilities will be built. For many communities, new or rehabilitated transportation facilities come with mixed blessings. Plans are brought and presented as a final product with little to no input from the community, resulting in a facility that meets the requirements of the designer without necessarily meeting the needs of the community. However, a growing number of examples show how transportation planners and designers working closely with the community throughout the entire process can produce outstanding facilities. In some cases, environmental mitigation was the predominant reason for extensive community involvement. In others it was foresight and the involvement of multi-disciplinary design and planning teams that brought outstanding projects to fruition.

These projects vary in scale from the intimate streetscape of historic Westminster, Maryland to the colorful rehabilitation of I-10 through downtown El Paso, Texas. Others include small details, such as the soon-to-be installed leaping salmon pedestrian overpass screen at the Chenowith Interchange in The Dalles, Oregon on I-84 and the flamboyant colors of the pathways interconnecting the Miami transit railway and redevelopment areas in Overton, Florida. Some examples have received especially high praise, such as Portland, Oregon's Max, a light rail system that is completely integrated into the fabric of the community, from the sign and information systems to the laying of the tracks and the surrounding pavement materials chosen for heavy pedestrian areas.

Each of these projects reflects the community in which it is located while also meeting all safety standards and guidelines. Visually, these creative and innovative projects stand out from traditional transportation facilities where designers followed "the book." These projects do more than provide facilities to meet the needed level of service - they create places with unique identities that become integral parts of their communities. The success of these places shows that there is a better way in which to plan and design transportation facilities. What is important to remember is that each community is unique and the design of each transportation facility should not only respect that but also respond to it.

Basic Research

Practical efforts to address visual quality and aesthetics in transportation must build on a basic understanding of how humans perceive and respond to the physical environment. There is a considerable body of research on aesthetics in the areas of environmental psychology, geography, and landscape architecture that has not been integrated into highway and related transportation literature. Much of the work that has been done was sponsored by federal land management agencies, the USDA Forest Service, the National Park Service, and the Bureau of Land Management. This literature has numerous techniques for identifying visually sensitive areas, determining public preference, and working with groups to achieve a successful project. Recent work developed under the auspices of the Federal Highway Administration (FHWA) National Scenic Byways Program has added to this body of knowledge.

By adopting some of the proven methodologies and research techniques and conducting much needed basic research, transportation agencies could develop tools that allow much greater objectivity in making aesthetic judgments. Likewise, much of the public resistance associated with aesthetic concerns could be answered early in the design process, avoiding costly delays and redesign late in the design process.

Value of Aesthetics

One explanation for why visual quality and aesthetics may not receive adequate attention in the planning and design of transportation facilities is that many of the benefits are difficult to quantify and are thus left out of standard cost-benefit analyses. The potential benefits include economic benefits, such as a savings in project cost due to reductions in delays in the design process or a boost in local economic development, as well as broader community benefits, such as the psychic value of a pleasing landscape or an increase in levels of safety and comfort.

The traditional approach to cost-benefit analysis focuses on direct costs, i.e. the costs of design and construction, and direct benefits, usually a reduction in congestion or travel time or an increase in capacity. The concept of "least cost" or "full cost" planning suggests that transportation facilities should also be evaluated with respect to indirect costs and benefits, both positive and negative externalities. This approach brings a broad range of environmental, social, and economic factors into the analysis; visual quality and aesthetics should be among them.

Design Challenges

Designers face an on-going challenge in addressing issues related to visual quality and aesthetics. To successfully integrate a roadway or other transportation facility into the physical and visual environment, the design need, topographic limitations, plant communities, significant cultural resources, historic, scenic, rural, and designed landscapes must be identified and considered. These elements make up the character of a particular location. The visual character of a location need not be rural to have a high degree of visual quality, nor developed to have a sense of place. Instead, a combination of various landscape types and existing visual resources of the transportation facility and its setting provides the facility with its own individual character. Design must address both the view of and the view from the facility, and must balance the local context with the regional context.

A project's design need is based on the projected development within a given area and the facilities necessary to safely move volumes of traffic or travelers from one place to another. Topographic constraints include not only the natural lay of the land, but the development upon it. Design criteria in one section of the country may not be suitable in another. Each locale (north, south, east, and west) provides its own visual and landscape characteristics. It should be noted, however, that basic aesthetic considerations are identical in all locales: what makes one project successful and another unsuccessful is the degree of attention to aesthetics and the care taken to integrate the facility into the adjacent landscape.

What should be incorporated in the design is the balance between the elements of function, proportion, order, form, line, color, and texture. All too often, a design fails when it does not integrate these elements, and simply relies on embellishments to make an aesthetically sensitive design. More times than not, this philosophy is ineffective, draws attention to itself, and results in a less acceptable design than if no treatment had been applied. What needs to be determined is how these aesthetic elements blend and are integrated into both the physical and visual landscape. Critical elements include, but are not limited to:

- Structures: bridge piers, superstructures;
- Edge delineators: walls, screens, fences, guard rails;
- Signage and lighting;
- Slope protection and form; and
- Vegetation: planting, maintenance.

For elements such as these, the following must be addressed: scale, color, texture, pattern, line, and form in the new facility in relation to the existing land form, natural vegetation, land use, and architecture.

These issues are receiving increasing attention from state and federal agencies. For example, the FHWA will soon be publishing a companion book to AASHTO's Green Book entitled "Designing Highways for our Communities and Countrysides." This guide of ideas and insights is meant to assist highway designers with more aesthetically-pleasing design solutions that are more acceptable to communities. State DOTs such as Rhode Island and Massachusetts have developed design and maintenance guidelines that will protect and enhance the visual quality of state roads. Rhode Island's guide covers facility design and maintenance of the state's highways, and deals with scenic byways in particular. Massachusetts' guidebook discusses tree maintenance and replacement for the Old Kinds Highway (Rt-6A).

Amongst all the elements of design, trees present designers with one of their greatest challenges. They are an important aspect of community identity and have emotional significance for the residents of communities, both rural and urban. Yet, safety concerns often dictate that trees be removed to create a clear zone. Trees should not be placed in the clear zone for any new construction or major reconstruction. However, the decision to create a clear zone that requires the removal of existing trees is an issue that should be presented to the public and addressed by a multidisciplinary design team early on. If communities consider existing trees a valuable resource, other options than complete eradication must be pursued. These include the installation of traffic barriers, the lowering of the design speed, or even complete redesign of the facility to incorporate the trees. It is not unusual for a community to value one specific tree and desire to preserve it. Transportation designers must balance safety with community values when considering facility design and tree preservation.

Innovation in Education and Communication

Innovations in both education and forms of communication are needed. Planners and engineers, for example, would benefit from education on the importance of and ways of addressing aesthetics and visual quality in the planning and design of transportation facilities. Ideally, interdisciplinary courses would be developed as a way of expanding the perspective of students and practicing professionals alike and as a way of demonstrating the importance of process. Innovative forms of communication, especially visualization techniques, will play an important role in education--and in public participation. Such techniques enable citizens to better evaluate proposed alternatives and formulate their preferences. Computer-based forms of publication, including the World Wide Web and CD-ROMs, facilitate the dissemination of visual examples.

RESEARCH NEEDS STATEMENTS

Title: Development of a model community- and place-based project development process that successfully incorporates visual quality and aesthetic concerns

Problem Statement: Traditional transportation system planning and design processes have often been single-purposed, environmentally myopic, and lacking in expertise of multiple disciplines and support of local communities. Community resistance to new and redeveloped facilities has increased. This resistance can be traced to several factors, including the lack of attention to visual quality and aesthetics.

While there are federal and state mandates that visual quality and aesthetics be addressed in planning and design of transportation facilities, a lack of criteria and guidelines for doing this means that visual quality and aesthetics have not been adequately addressed. Recent examples - particularly examples of developing management plans for scenic byways - are emerging which could provide insights or models. These examples have several common threads: 1. they integrate the local community into the process right from the beginning; 2. they are place-based, responding to the uniqueness and distinctiveness of each bioregional unit; 3. they are multidisciplinary; 4. issues, solutions, and guidelines developed in the planning phase of a project are carried through all phases of design and implementation; and 5. they address multiple objectives.

The community needs to be contacted early about a possible transportation project. Residents' understanding of the need will help them participate in the development of solutions and actions and advocate for a project's development within the community context. The community will put its signature on its own place.

Place-based planning begins with the larger context, the bioregion, and then identifies and characterizes smaller units. These units provide the framework for planning by making the connection between resource assets, community values, and implementation opportunities.

Professionals from many disciplines, particularly planners, landscape architects, cultural and natural resource specialists, and traffic and transportation planners and designers bring knowledge and expertise to a community. They facilitate the development of a community-initiated, place-based solution.

Solutions, activities, and guidelines that are developed by communities and supported by the multidisciplinary project team need to be carried through design, construction and operation and maintenance phases of a project, through all activities within these phases.

Single-purpose, single-objective solutions are becoming less and less popular and more and more difficult to fund. Solutions and actions that meet multiple objectives and have diverse stakeholders will enfold a larger constituency. Many more funding sources will be available for implementation.

Proposed Research: The proposed research is to identify case studies from the United States and other countries of project development processes that successfully incorporate visual quality and aesthetic concerns. These case studies will provide a basis for guidelines for project development processes. Specific tasks are as follows:

1. Identify cases from the United States as well as other countries that have successfully incorporated visual quality and aesthetic concerns into a comprehensive, community- and place-based approach.

2. Develop in-depth case studies of these successful examples. Interview local community groups, agencies, and multidisciplinary team members involved in each project.

Gather information on the processes for each project and on what worked and what didn't work.

3. Evaluate the case studies to identify the steps that should be included in a successful process. Recognize differences in the planning, design, construction, operations and maintenance phases as well as regional differences.

4. Document and disseminate results using traditional and electronic means. Emphasize graphic examples.

Cost: $700,000
Duration: 18 months

Title: Linking Research on Human Aesthetic Perception of the Landscape to Transportation Concerns and National Forum on Aesthetics In Transportation

Problem Statement: There is little objective research on transportation corridors that can assist officials in making sound aesthetic judgments. However, there is a significant body of knowledge developed in the fields of environmental psychology, geography, landscape architecture and architecture, that has direct application to transportation and design. There is also an important library of methodologies developed by federal agencies such as the Bureau of Land Management, National Forest Service, National Park Service, and Environmental Protection Agency, to assist them in making aesthetic decisions. There is a need to summarize and relate this body of material to transportation practice and to disseminate findings to the transportation community.

Proposed Research: 1. Research is needed to assemble the research on visual quality and aesthetics to support transportation planning and design. The objectives of the proposed work are to:

- Review and summarize existing research on human perception of aesthetics and the environment that relate to transportation issues; and
- Identify specific techniques and methods that can be used to improve the aesthetic qualities of transportation corridors.

2. Evaluate selected research efforts relative to transportation issues.

3. Conduct National Conference on Aesthetics and Transportation. Select and invite researchers to prepare position papers that link their research to transportation issues. Conduct the conference. Publish the proceedings.

Cost: $400,000
Duration: 18 Months

Title: Quantification of Benefits of Aesthetic Considerations in Transportation Facilities

Problem Statement: Evaluation of proposed transportation facilities has often been restricted to areas such as cost/benefit analysis, travel-time savings, emissions reductions, etc. In quantifying the externalities (i.e. spillovers) - both positive and negative - of a given transportation facility, an abundance of data has been produced. These data usually speak to a particular mode (e.g. transit or highways) and to specific aspects that are easily quantified (e.g. ridership or arterial capacity); data on less-readily quantifiable concerns, including aesthetics and visual quality, is lacking. Consequently, the element of aesthetic and visual quality in this multi-modal/multidisciplinary environment is not allocated an equal or sufficient amount of consideration. Often, aesthetic and visual qualities are not considered until after a decision or plan for an area or region is implemented; the economic impacts of this practice, in terms of delays and unplanned costs, are not analyzed. A comprehensive analysis of the economic efficiency and other community benefits inherent in the consideration of visual and aesthetic qualities would be beneficial to all participating parties (community, elected officials, MPOs, state DOTs, transit operators, etc.) in the development of regional transportation plans.

Proposed Research: The goal of this research is to quantify the benefits of aesthetic considerations in transportation facilities, including benefits that are easily quantifiable as well as those that are often considered non-quantifiable. This research will provide an economic justification for investments in aesthetics and visual quality and will provide guidelines and methods for communities to incorporate aesthetics and visual quality into cost-benefit analyses. The research includes the following tasks:

1. Review of research relevant to the quantification of benefits.

2. Evaluation of the benefits of investments in aesthetics and visual quality in selected projects. Potentially quantifiable benefits include:

- increased property values;
- reduction in stress for users of the facility;
- increased sense of security for users of the facility;
- increased and improved opportunities for joint-use of the facility (e.g. bikeways parallel to highways); and

- increased tourism.

3. Evaluation of community willingness-to-pay for different types and degrees of investment in aesthetics and visual quality. Analysis of similarities and differences between regions.

4. Development of guidelines for incorporating aesthetic and visual concerns into cost-benefit (or "full-cost" or "least-cost") analyses.

5. Documentation and dissemination of results using traditional and electronic means.

Cost: $400,000
Duration: 18 months

Title: Best Practices in the Aesthetics of Transportation Facility Design

Problem Statement: State and local jurisdictions throughout the country have developed innovative approaches to the design of transportation facilities. These efforts can provide useful guidance to other jurisdictions struggling with similar issues. It is important to identify, document, and disseminate these efforts. Recognizing that the planning and design process can be bogged down by minutiae, it is important to review and evaluate a broader approach that crosses both modal and place boundaries. To reach this goal, there is a need to research and evaluate the projects that work by evaluating and identifying the criteria under which the best projects were designed and developed. There is a need to identify what role multidisciplinary teams played throughout the process and what role the community played in the process. There is also a need to understand the regulatory process and how it has affected these projects, beneficially and negatively.

Proposed Research: 1. Identify and prioritize design and aesthetic issues through a survey of practitioners (e.g., community planners and transportation facility designers). Potential issues include but are not limited to: lighting, tree conservation, signage and communications systems, and transportation appurtenances.

2. Identify best practice examples of the top priority issues that include a range of transportation modes (roads, transit), contexts (urban, rural, suburban), and scales (regional, local). Identify and define the criteria under which these are considered the best practice.

3. Disseminate the resulting information through both traditional and non-traditional means of communication.

Cost: $150,000
Duration: 18 months

AIR QUALITY

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BACKGROUND PAPER

The Clean Air Act Amendments of 1990 (CAAA) include provisions to control carbon monoxide, ground-level ozone (urban smog), particulate emissions, and other air toxics from motor vehicle engines. It seeks to reduce vehicle emissions through a combination of cleaner vehicles, cleaner fuels, and transportation programs and projects that will improve traffic conditions, alter driving behavior, or make alternatives such as transit or other modes an increasingly important part of the transportation network. In December 1996, new air quality standards were proposed for ozone and particulate matter, representing significantly more difficult targets to meet.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) reinforces the need for the nation's nonattainment areas to achieve the National Ambient Air Quality Standards (NAAQS). ISTEA emphasizes an improved planning process that includes consideration of multimodal investments, land use decisions, financial constraints and air quality improvement. Through its planning framework and specific funding programs, ISTEA gives State and local officials the tools to adapt their plans to assist nonattainment areas in achieving the NAAQS. The Congestion Mitigation and Air Quality Improvement Program (CMAQ) and the Surface Transportation Program (STP) specifically enable the funding of transportation projects that reduce emissions including the transportation control measures (TCMs) listed in the CAAA. Together, CAAA and ISTEA provide complementary approaches to decrease transportation-related emissions. In practice, while the CAAA sets air quality requirements and milestones, mandates further improvements to vehicles and fuels, and requires greater integration of transportation and air quality planning, ISTEA provides the funding flexibility to target the use of transportation funds to promising strategies to reduce transportation-related emissions.

Research efforts should investigate the transportation implications of the proposed new ozone and particulate standards. Research should assess the significance of the proposed standards on current approaches to reach attainment, address the anticipated effectiveness of regional control strategies, identify the impacts of the new standards on the transportation planning process, and assess the conformity requirements in light of new standards and new, larger nonattainment areas. Impacts of new standards on ISTEA legislation should be investigated as well as current and possible future linkages between the CAAA and ISTEA. The rules proposing the new standards will be made final in 1997 with their implementation to follow. Given this very short time frame, this is considered a high priority area which should be addressed as soon as possible.

An important topic in developing transportation and air quality plans and programs is to identify the most effective transportation strategies to improve mobility and reduce emissions given Federal and other available funding. For instance, some TCMs, such as high occupancy vehicle (HOV) lanes, transit, or intermodal facilities, require large capital investments, while others such as pricing and regulatory mechanisms may be of relatively low capital intensity. It is important that each state or area decide among alternative investment strategies based on the relative costs and benefits given the multiple objectives served by transportation investments. Further, the long term impacts of certain capital investments is un-

clear, specifically whether such investments effectively induce new travel demand. To provide assistance to states and metropolitan areas, research on the relative cost effectiveness of alternative transportation investments and TCMs in reducing vehicular emissions is needed. In addition, research is needed into the question of the long term impacts of certain investments on inducing demand and/or satisfying latent demand.

To achieve national air quality goals, the CAAA require the most polluted areas to limit growth in vehicle travel by reducing Single Occupancy Vehicle (SOV) travel and VMT. Control of total vehicle miles traveled (VMT) requires broad support from jurisdictions beyond the transportation and air quality communities including the business community and general public. According to a national survey, the reasons for increased VMT during the past 20 years included a dramatic increase in the number of workers, an increase in the number of jobs located in the suburbs where fewer travel alternatives are offered and distances are greater than suburb-to-city travel, increases in vehicle ownership, a decrease in vehicle occupancy for work trips, and lower fuel costs in real terms compared to the costs in 1950. Growth in VMT has been further reinforced by the land use patterns of dispersed residences and jobs. Research is needed to explore viable and effective strategies to ensure that rising VMT will not eventually overtake mobile source emissions improvements. Whether and when emissions will rise with VMT, to what level, and what can be done at present and in the future, are important issues to be studied.

Particulates are a significant contributor to human health problems, including asthma, chronic respiratory irritation, toxic exposure, and possible carcinogenesis. Combustion of transportation fuels is implicated as a major source of these fine particles, with tire, engine and brake wear being contributors. In recognition of these effects, EPA is proposing stricter standards for particulates, notably a standard for extremely fine particle matter ($PM_{2.5}$). Research is needed to determine the contribution of mobile sources to the particulate problem, the relative contributions of tire, brake and engine wear, de-icing sands and salts, and other mobile sources; and information about what control strategies are reasonably available. Additionally, the cost effectiveness of various strategies should be researched and documented.

Heavy duty vehicles (8,500 lbs. and over) are significant contributors of NOx, SOx, and PM_{10} emissions, and also contribute to CO and HC emissions. Emission rates for heavy-duty vehicles are related to the vehicle's operating characteristics including time of day of travel, temperature, engine classifications and loads. Research is needed to specifically focus on emissions from heavy-duty vehicles and to understand and document the emission rates of heavy-duty vehicles as a function of engine load and on road activity, to explore reasonable control strategies to reduce emissions from heavy-duty vehicles, and to develop methods to analyze heavy-duty emissions as a separate component in future travel demand modeling.

A small fraction of light-duty vehicles is responsible for a large fraction of fleet emissions. These vehicles typically exhibit high emission rates during all operating conditions. Research is needed to identify these vehicles ("high emitters") in urban areas and quantify their emissions so that improved emission reduction strategies targeting this significant subset of the vehicle fleet can be developed and implemented.

The need for information required by CAAA and ISTEA guidance and regulations published on VMT forecasting, transportation and air quality planning, state implementation plan development, motor vehicle inspection and maintenance, the CMAQ program, TCMs, and conformity have placed a significant burden on state and regional officials. Depending on their classifications, some nonattainment areas have to meet mobile source requirements relating to inspection and maintenance programs, vapor recovery systems, clean fuel fleet programs, VMT limitations, reformulated gasoline, or oxygenated fuels. The development of a systematical network for assessing regulations, policies, and compliance issues is needed. In addition, the impacts of these regulations, the models to be used, and changes in compliance requirements should be evaluated efficiently and systematically.

The CAAA includes fuel along with vehicle technology as a potential source and target of emission reductions. The CAAA mandates that improved gasoline formulations be sold in some cities to reduce emissions of carbon monoxide or ozone-forming hydrocarbons. Other programs set low vehicle emission standards to stimulate the introduction of even cleaner cars and fuels. Research to identify the most promising ways to increase the market for and use of alternatively fueled fleets is needed, with an emphasis on the early transition of publicly and commercially operated fleets--including needed fueling infrastructure.

Experts and the public have become concerned about previously unrecognized environmental threats such as greenhouse effect (global warming), acid rain, and air toxics. The relationships between these threats and air emissions from transportation sources become new areas for needed research. For example, climate observation shows that the human-induced climate change has been caused by changing composition of the atmosphere and increasing air pollutants. As selected for emphasis, car-

bon dioxide (CO_2) and methane (CH_4) are increasing in the atmosphere and play a role in governing the global climate by absorbing and re-emitting infrared radiation that would otherwise escape directly into space, thereby trapping heat. These heat-trapping gases keep the earth's surface warmer than it would otherwise be. In addition, because ozone also acts as a greenhouse gas, an increase in ozone concentration in the free troposphere will have climatic consequences. The projected climate changes are further enhanced by other air pollution problems created by people, such as acid precipitation, which involves a complex pattern of emission sources of SO_2 leading to complicated chemical and physical reactions in the atmosphere.

Many new topics need to be explored such as: the impact of alternative fuels on greenhouse gases; model development for estimating CO_2 from motor vehicles based on fuel consumption; feasibility of setting international greenhouse gas standards and impacts on the economy; feasibility of future long term emission reductions in mobile engine exhausts; evaporative emission controls during refueling, storage, and dispensing; the role of emission credit programs in regional emission reduction; and the study of the linkages between land use and air quality.

RESEARCH NEEDS STATEMENTS

Title: Particulate Matter Source Apportionment and Control Strategy Synthesis

Problem Statement: Characterization of the size, distribution, and effects of airborne particulate matter has identified fine particles of 2.5 microns and less in diameter ($PM_{2.5}$) as a significant contributor to human health problems, including asthma, chronic respiratory irritation, toxic exposure, and possible carcinogenesis. In recognition of these effects, EPA is proposing standards for this extremely fine particulate matter in ambient air that will supplement standards for 10-micron and smaller particles (PM_{10}) already in place. Combustion of transportation fuel is implicated as a major source of these fine particles, with tire, engine and brake wear, road de-icing substances, and re-entrainment of road dust also identified as transportation-related contributors. Imposition of more stringent emission standards and controls on these sources will result in substantial costs for engine and vehicle manufacturers, petroleum producers, and owners and operators of commercial trucks. However, the allocation of responsibility across sources and the need for specific source controls have not been reliably established. For example, there is apparent inconsistency between the share of fine particles presumably represented by $PM_{2.5}$ and their share of total ambient particulate mass, which may incorrectly implicate some sources beyond their actual culpability. Moreover, the contribution of mobile sources cannot accurately be established without comprehensive speciation, which has not yet been performed in most areas with high ambient levels of fine particulate. (EPA is expected soon to issue monitoring and assaying protocols that will enable this to occur.) Finally, there may be yet unidentified synergism between ozone control strategies already in place or soon to be implemented and effective means of PM_{10} and $PM_{2.5}$ reduction.

Proposed Research: (1) Review available data on recorded concentrations of fine particles and their locations, and special studies conducted on the topic; (2) obtain fine particle measurements near and at longer downwind distances (up to 500 meters) from a cross section of roadway types in urban areas situated in differing climatological regimes (e.g., arid to semi-arid, forested, agricultural prairie, humid to subtropical), focusing on the variation by vehicular speed, traffic volume, and composition; (3) perform speciation and source apportionment studies for concentrations measured near each roadway, and subtract background concentrations measured upwind of the source; (4) quantify relationships among the contributions by re-entrained dust; diesel combustion; gasoline combustion; tire, brake, and engine wear; and de-icing sand/salts; and explore how these might differ by traffic volume and level of service as well as seasonality, wind and atmospheric stability conditions; (5) attempt to identify differences among fuels and engine displacements using bench testing, as necessary; (6) develop a synthesis of reasonable available control technologies, including those already in *ozone* control strategies and SIPs. Possible follow-on research would include identification of cost-effective controls that target the most important contributors. *EPA's interest in supporting this project should be explored.*

Cost: $450,000
Duration: 24 months

Title: Heavy Duty Vehicle Emissions and Activity Levels

Problem Statement: None of the current research projects focus specifically on the emissions inventory for

heavy-duty vehicles. Research in the area focuses primarily on light duty vehicles because they are the largest emission component of the mobile source problem. However, Heavy Duty Vehicles (HDVs), those vehicles above 8,500 pounds gross vehicle weight rating, are significant contributors of NOx, SOx, and PM_{10} (exhaust) emissions, and also contribute to CO and HCs. Emission rates for HDVs are related to the vehicles' operating characteristics (such as time of day), engine classifications and loads.

Proposed Research: Undertake a research effort for heavy-duty vehicles that encompasses (1) a characterization of the emission rates as a function of engines (size, maintenance, rebuilds, etc.), and engine load parameters or load surrogates (including payload, idling, and speed acceleration profiles), (2) area-specific studies of on-road activity that can be reliably linked to emission rates for short and long-distance motor carriers and for inter-city buses, (3) an analysis of the effectiveness of HDV emissions testing procedures and modeling techniques (using data from CARB, EPA, or other parties), (4) the implications of new engine technologies developed for the 1998 HDV emission standards and the proposed 2004 emission standards, and (5) a demonstration of how the framework could be used to evaluate operational changes to achieve emissions reductions. The research will not encompass proprietary information on HDV fleets' routes, destinations, or origins. Because the pollutant emissions and type of driving modes of these vehicles are different from passenger cars, this type of data would allow the analysis of HDV emissions as a separate component in future travel demand modeling.

Cost: $1,000,000
Duration: 36 months

Title: Land Use/Neo-Traditional Development and Air Quality

Problem Statement: Traditional policies and market forces direct growth and development in American cities to low density and land-use-segregated development. This development pattern results in greater transportation infrastructure requirements and costs, limited access to alternative modes for much of the population, and degraded air quality. Recent studies have indicated that higher density, mixed use, transit and pedestrian oriented development may reduce vehicle-trip making. The results of these studies, generally of older traditional urban neighborhoods, vary significantly, but after controlling for income and household size do generally indicate a reduction in vehicle use. Neo-traditional developments are being proposed and to a limited extent built as a higher density, mixed use alternative to traditional suburban development. Little is known about the potential market penetration of such developments or about the impact of such developments on air pollutant emissions.

Proposed Research: (1) Conduct case studies to identify the impact of neo-traditional development patterns in suburban and in-fill settings on personal transportation decisions (including auto ownership and trip making by motorized and non-motorized modes). (2) Identify development pattern factors that impact vehicular travel and can be measured and included in travel models. This includes identification of factors that influence use of non-motorized modes. (3) Identify and estimate the market potential for high density/mixed use development in various metropolitan settings (including in-fill versus suburban locations, and high growth versus stable metropolitan areas). (4) Identify obstacles to implementation of in-fill and neo-traditional developments from both the public sector (for example zoning and regulatory requirements such as street width and access control) and private sector (for example financial institutional lending practices and parking standards set by private investors). (5) Estimate the time frame for implementation. (6) Estimate the local and regional level impacts on vehicle use, speed/acceleration profiles and resultant modal emissions, and transportation infrastructure impacts of implementing such development patterns in a number of prototypical metropolitan areas. These areas should be chosen to represent various regional growth patterns such as areas experiencing fast versus slow growth, and areas with declining central cities versus stable or growing central cities.

Cost: $750,000
Duration: 60 months

Title: Transportation Implications of Proposed Changes to the National Ambient Air Quality Standards (NAAQS)

Problem Statement: In November 1996 the Environmental Protection Agency will propose changes to the NAAQS for ozone and particulate matter (PM). The new ozone standard is expected to be significantly more stringent, and a new standard for very small particles ($PM_{2.5}$) will likely be proposed in addition to retaining the current standard for PM_{10}. The proposed rules are expected to become final in June of 1997. For ozone and PM, the number of counties in nonattainment is expected to triple, indicating increases in the number and the size of current nonattainment areas. These new standards could require fundamental changes in the approach used to plan for and improve air quality. New control strategies or a shift toward more regional control strategies may be necessary, and new considerations regarding ozone transport and

VMT may arise. The new NAAQS could also precipitate changes to transportation planning on a par with those effected under the 1990 Clean Air Act Amendments (CAAA) and create new administrative burdens for federal, state, and local agencies. Further, the linkages forged between the ISTEA and the CAAA to blend transportation and air quality concerns, including the conformity provisions, the CMAQ program, the emphasis on TCMs, development of State Implementation Plans, and the application of highway sanctions, may be disrupted. The full nature, magnitude and scope of these changes is unknown, and research is needed to prepare the transportation community to address them.

Proposed Research: 1) Determine the significance of the proposed standards on current approaches to reach attainment. Specifically address the anticipated effectiveness of regional control strategies, such as inspection and maintenance programs and clean fuel programs, versus local control programs, such as traditional TCMs. 2) Identify the impacts of the new standards on the transportation planning process and the mismatch between the size of metropolitan areas where planning requirements (fiscal constraint, etc.) are currently applied and new, larger nonattainment areas. Identify data requirements and model developments needed to apply the transportation planning process to larger areas. 3) Assess the current conformity requirements in light of the new standards and new, larger nonattainment areas. Suggest changes to the current approach taken under the conformity regulation. 4) Determine the effect of the new standards on current and possible linkages between the CAAA and the ISTEA. Suggest legislative, regulatory and administrative changes to insure that effective transportation programs and planning processes to improve air quality are aligned with the latest approaches to effect clean air resulting from the new standards. EPA's interest in supporting this project should be explored. This project should start as soon as possible after the final rules establishing the new NAAQS are promulgated.

Cost: $250,000
Duration: 18 months

Title: Subfleet Technology and 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" (i.e. malfunctioning and tampered vehicles) typically exhibit high emissions rates under all operating conditions. High emitters are usually defined relative 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 while 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. New methods to identify these vehicles in urban areas (both spatially and temporally) and to quantify their emissions will lead to improved emissions modeling and will provide a basis for improving emission reduction policies that target subsets of the vehicle fleet.

Proposed Research: Undertake a literature review on light-duty vehicles high emitter definitions for CO, CO_2, HC, and NOx, and evaluate the previous studies to ensure that technology group definitions represent groups of vehicles that behave similarly in terms of emissions production. Based upon the literature review, and analysis of existing data, identify the cutpoints that should be used by pollutant (in grams/mile or grams/second) to define high emitting vehicles for various technology groups. 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 such that the fraction of high emitting vehicles for each technology group can be identified and the activity can be tied to appropriate emissions rates in the MOBILE model. Develop basic methods to apply on-road technology group fractions and emitter distributions within the context of 4-step travel demand modeling and HPMS modeling frameworks so that local subfleet information can be used in the MOBILE6 emissions modeling process. Implement these basic methods in three urban areas that exhibit diverse geographic, socioeconomic, aggregate fleet, and inspection and maintenance program characteristics. Based upon analytical results for these areas, 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, also analyze the overall impacts of the highest emitting vehicles in the fleet. Identify technology or socioeconomic factors that appear to influence the fraction of high emitters in operation throughout the network. Based upon the cross-city results, analyze the potential effectiveness of control strategies designed to reduce the on-road fraction of high emit-

ting vehicles within and across technology groups. 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 upon high emitter ownership and socioeconomic correlations.

Cost: $300,000
Duration: 18 months

Title: Pollution Emissions from Specialty Fleet Vehicles

Problem Statement: Conventional motor vehicle emissions inventories and control strategy analyses include estimates of air pollutant emissions that are based on average emission rates and estimated VMT for broad classes of motor vehicles (for example, light-duty gasoline vehicles, which roughly corresponds to passenger automobiles). Vehicle emission factor models such as MOBILE may understate emission rates for special-purpose subgroups that are used particularly intensively or that operate under conditions that tend to produce elevated emission rates. These subgroups include public fleets, taxis, rental fleets, panel trucks used by the professional trade, utility vehicles, shuttles, and many others. In addition, the procedures commonly used to estimate VMT, including regional travel demand models, fuel sales, and vehicle counts on major urban arterials, may understate or even omit entirely the contributions of these vehicle subgroups.

Proposed Research: (1) Clarify the extent to which emissions (CO, HC, and NOx) from special-purpose vehicles are already recognized in developing typical motor vehicle emissions inventories and control measure analyses. (2) Develop emission rates, using MOBILE or by gathering real data from inspection programs, for a number of special-purpose vehicles at the metropolitan level (rather than relying on fleet-wide of these parameters). (3) Estimate activity (speeds, idling, VMT, etc.) possibly using data gathered from instrumented vehicles. (4) Use the data to estimate total emissions from these fleets and compare the result to the contribution of light-duty vehicle emissions in the metropolitan area. (5) In addition, the research should identify appropriate control strategies, such as conversion to alternative fuels, scrappage, or age limits for operation for application to specific vehicle classes, to achieve more accurate inventories of total motor vehicle emissions and development of more effective policies to reduce these emissions.

Cost: $500,000
Duration: 30 months

Title: Seasonal and Episodic Transportation Measures to Avoid Exceedances

Problem Statement: A number of regions have developed seasonal and/or episodic transportation measures to reduce transportation-related emissions during periods of potential high ambient ozone and carbon monoxide levels. These approaches generally include broadly based public information and outreach campaigns to minimize motor vehicle travel during days projected to have high pollutant levels. These programs have attracted significant employer involvement and support. While some evaluation has been done of their effectiveness, their actual results in reducing emissions are uncertain. Some areas use these measures as contingency measures to avoid ozone exceedances, others wish to claim credit for the emissions reduced in their State Implementation Plans (SIPs). To date the EPA has discouraged episodic or seasonal strategies, however, recently they have shown an interest in investigating the efficacy of such measures. Recently, the EPA commissioned a study of current episodic measures including a preliminary assessment of their effectiveness.

Proposed Research: This research would develop a menu of program components and resources appropriate for various air quality areas including scenarios for both episodic and seasonal measures arraying the pros and cons of each potential approach. The research would include the following components: 1) Define a range of transportation behaviors (such as mode shifts, trip substitutions as well as driving to minimize extreme modal emissions of heavy accelerations and high speeds). 2) Define and estimate potential targets by specific transportation market niches through various market research techniques such as focus groups. 3) Estimate the potential and the magnitude of marketing resources that would be necessary to achieve the potential targets, drawing on the experience of such systematic public awareness programs as energy conservation, waste recycling and non-smoking. 4) Estimate the emissions reductions, energy and carbon dioxide impacts of the varying marketing approaches. 5) Identify and develop tools to predict likely travel behavior and emission reduction benefits, and evaluation mechanisms to measure and quantify the results such as personal travel surveys, traffic monitoring, transit boarding counts, and fuel sales. 6) Demonstrate how these tools can be applied in one area. 7) Estimate the cost-effectiveness of the various measures. 8) Identify cooperative mechanisms for the public and private sector to sustain the public awareness program and measures over time. 9) De-

velop criteria to be met if such measures are to be included for emission reduction credits in SIPs including: permanence (long term commitment and resources to sustain the public awareness effort); quantification; and enforceability (including that there is an established mechanism to continue to monitor the program and results into the future).

Cost: $250,000
Duration: 24 months

Title: Modification of HPMS for Air Quality Analysis

Problem Statement: The Highway Performance Monitoring System (HPMS) was developed as a tool to track national vehicle miles traveled (VMT) and roadway conditions. Although this system was not developed for air quality analysis purposes, EPA requires that it be used for evaluating nonattainment area VMT in State Implementation Plans. A variety of air quality control measures will automatically be invoked if HPMS VMT exceed SIP projections by 3% or more. Proposed changes to the National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter may greatly increase the number of nonattainment areas forced to use HPMS data. Many potential nonattainment areas under the new NAAQS lack adequate travel demand models and will be required to use HPMS data in SIP development. Some HPMS facility classifications are different than those used in travel demand modeling. Due to problems with data compatibility, HPMS data cannot readily be used to evaluate and improve travel demand model VMT estimates. In many areas, HPMS may not be the most accurate method of reporting VMT. More extensive counts or Intelligent Transportation Systems, Congestion Management Systems data may be available and may be more accurate than HPMS.

Proposed Research: For urban areas of varying size, evaluate the current accuracy of HPMS by comparing estimates to actual ground counts and examining the sampling network for potential bias. Based on this work, determine the overall uncertainty of HPMS-derived regional pollutant emissions estimates. Make recommendations on how to supplement or modify HPMS to achieve the desired accuracy. Develop guidelines for making HPMS facility types consistent with travel demand model facility types and for applying HPMS or a similar system in areas that may soon face new conformity requirements under the proposed changes to the National Ambient Air Quality Standards.

Cost: $200,000
Duration: 24 months

Title: Latent and Induced Demand from Effective Capacity Changes

Problem Statement: Driver trip-making response to added capacity has been the subject of several studies. This work generally indicates the potential for added capacity to increase demand, so that resultant flow improvements may be only temporary. The reverse phenomenon is of interest as well: reductions in capacity through traffic calming, road closure, etc. may result in diminished demand. More study is needed to determine the demand implications of a wide variety of measures that effectively increase capacity, including add-a-lane HOV, pricing, new transit services, ITS and other traffic flow improvements. Flow improvements can also serve as an incentive for new development and changes in land use at the local level. Hence, emissions from new area and indirect sources may also be facilitated by roadway capacity increases.

Proposed Research: Review literature on latent and induced demand. Identify projects or areas in which change in demand has been documented in response to increases or decreases in effective capacity. Examine and synthesize data from these examples. Effects of changes in occupancy restrictions for HOV lanes should be studied, as should volume changes in response to transportation control measures, including traffic flow improvements and traffic calming. The relationship between the growth of area and indirect source emissions along expanded highway and transit corridors should also be investigated. Identify MPOs that have included or propose to include in their four-step models feedback to trip generation, trip distribution and time of day of travel to reflect latent demand phenomena. Produce guidelines for adjusting models estimating highway vehicle emissions to reflect the consequences of changes in effective capacity.

Cost: $300,000
Duration: 24 months

Title: Ambient Microscale Monitoring for Project Compliance with the National Ambient Air Quality Standards

Problem Statement: Of the National Ambient Air Quality Standards established by the Environmental Protection Agency, carbon monoxide (CO) and particulate matter (fine dust less than 10 microns in diameter) are generally considered to have a near facility/ hot spot or micro scale level impacts, i.e. their concentration can change significantly within a short distance of the transportation facility. Transportation conformity require-

ments establish complex analysis requirements for transportation projects located in areas designated non-attainment or maintenance for these pollutants. In these areas a project cannot proceed if the analysis shows the action may cause or contribute to a new violation of the standards and/or increase the number or severity of existing violations. In attainment areas such analysis may raise concern that advancing the project could bring the area into non-attainment status.

The existing methodology is not well suited to deal with the form or stringency of the standards. Traffic models are constructed to describe average, not extreme, operating conditions. Emission models produce regional average emission rates which may not be appropriate at the sub-regional or project level. Dispersion models do not perform well under the conditions most likely to create hotspot conditions (calm or near calm wind speeds). Background concentrations are often unknown. To overcome these uncertainties and limitations, conservative modeling assumptions are used for CO analysis. Microscale analysis models for fine particulate have not yet been released by EPA but will doubtless suffer the same shortcomings. Unfortunately, while monitored data is trending down, analysis results are indicating increasing concentrations. Project sponsors would likely accept a short term need for monitoring as an alternative to the current methods used.

Proposed Research: Develop detailed methods and technical guidance for ambient monitoring at microscale levels for determining site and background concentrations. Determine if it is possible to directly measure pollutant levels in short-term direct monitoring programs (day, week, month, 3 month) to give reasonable estimates of the potential to exceed standards at the project location. An effort should also be made to combine this approach with existing screening methods. This research would allow for rapid and reliable determination of hot spot potential for CO and particulates.

Cost: $500,000
Duration: 36 months

CULTURAL RESOURCES

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BACKGROUND PAPER

Agency sponsors of transportation projects have a continuing responsibility to identify, evaluate, and consider project effects on cultural resources in a venue of changing criteria, standards, regulations, and priorities. While thousands of previous investigations were performed and continue to be performed in compliance with Section 106 of the National Historic Preservation Act of 1966, as well as other federal and state laws and regulations, the state DOTs and other agencies are faced with a constantly evolving and changing situation which increasingly requires the re-evaluation of existing procedures, techniques, approaches, and resources.

Our cultural heritage has been investigated in association with transportation projects since the inception of the regulations mandating the consideration of project effects on cultural resources more than three decades ago. The knowledge gained from these investigations often never leaves the specific project files of the sponsor agency's archives. The dramatic increase of survey, excavation, evaluation, and recordation efforts for cultural resources associated with the maintenance and improvement of our nation's transportation corridors, and the need to successfully complete highway, bridge, and other transportation projects under various constraints, requires better information integration, synthesis, and dissemination.

Over the past few years, there have been questions emanating from the offices of the transportation agencies, cultural resource management professionals, the State Historic Preservation Offices, as well as other agencies regarding the quantity of data being recovered from these investigations, potential for information redundancy, repetitive investigations and studies, and the lack of broader-based research. Although the identification, evaluation, and consideration of these nonrenewable resources is consistent with the spirit of preservation, repositories are increasingly overwhelmed with the materials of our distant and recent past. Moreover, cultural resource investigations conducted for transportation projects seldom look beyond the domain of the specific project to disseminate the results of the findings. Many of the state preservation offices maintain the files, reports, and site survey forms from investigations conducted within their jurisdiction, but few have either obtained the necessary funding and/or support personnel to aggressively disseminate the data or even pursue the applicability of the available data as a management, scholarly, or educational tool.

In response to these concerns, one of the most widely discussed topics has been the need for centrally indexed (computerized) cultural resource databases for cultural, historical and archaeological properties. The development of computerized statewide and/or regional cultural resource databases would serve as an important management tool to afford improved efficiency and effectiveness in the project planning, review, and approval process, as well as encourage scholarly and educational pursuits through the utilization and application of all types of data associated with cultural, historical, and archaeological studies. As envisioned, database integration, information sharing among historic preservation professionals and agencies, and networking would allow for the automation of the existing manual systems with faster and more accurate results; expand the interpretation of data to analyze trends that could be used to minimize redundancy in data collection; improve cultural resource information exchange; promote more efficient cultural resource man-

agement and improve the coordination of state archaeological and historical programs; provide important site location data for making decisions about future studies (i.e., predictive modeling studies); and stimulate and improve broad-based research of our cultural history.

Another issue of concern for the sponsors of transportation projects across the country is the interpretive variability of the intent of the regulations and laws mandating cultural resource investigations. As formalized, the underlying intent of the laws and regulations is the identification, evaluation and consideration of cultural, historical, and archaeological resources. The actual implementation of state policies and procedures that define the techniques, level of effort, and detail expected in these studies frequently tends to be extremely rigorous and costly. A review of investigations performed over the past decade may provide valuable information for current and future projects and may benefit State DOTs and historic preservation specialists attempting to compile basic guidelines for transportation projects.

The ambiguity and frustration in performing cultural resource investigations for transportation projects is further complicated by the difficulty in defining study area limits, areas of potential effect, and resource boundaries. Ongoing and unresolved issues that are generally handled on a project by project basis include the delineation of the right-of-way, take areas, and temporary construction zones, as well as the need, if any, for additional buffer zones outside the legal limits of the project. There also is the issue of research conducted on private property (rights of entry and ownership of data) and the dilemma of defining site boundaries and assessing impacts when only a portion of a resource is located within the area of potential effect. Last but not least, is the difficulty of assessing impacts to linear cultural resources such as former transportation features. In many areas of the country, the modern transportation system superseded earlier forms of transportation such as canals, trails, railroad and trolley lines, and toll roads or turnpikes. Given the lack of any formal guidelines, the problem, especially for smaller projects, is how to evaluate these types of resources within the scope of a specific project without performing extensive research on the entirety of the resource.

As the interpretation of Section 106 and historic preservation standards continues to evolve, there have been few innovations in the area of preservation and mitigation strategies for endangered cultural resources. New techniques and methodologies for the identification and evaluation of archaeological resources continue to be explored and implemented; however, little time and energy have been devoted to their ultimate use and management. Although avoidance of significant cultural resources is always the preferred alternative, full scale data recovery of archaeological sites or HABS/HAER recordation of buildings and structures prior to their demolition are typically employed as mitigation measures on transportation projects. This is perceived as the traditionally accepted, yet costly, solution for many transportation project sponsors who are charged with the responsibility of maintaining or improving the transportation system within time and budgetary constraints. As previously mentioned, the drawback to data recovery/recordation mitigation measures is that the information recovered is forwarded to the state or federal repositories where direct access to the benefits of this research by the public is limited. Mitigation measures such as in-place preservation or formal burial of archaeological sites, mitigation banking, or the adaptive re-use, dismantling and/or relocation of historic properties might be reexamined both for their applicability and effectiveness as a preservation strategy, and for their potential to contribute cost-effective solutions to transportation-related projects while simultaneously protecting vital fragments of our nation's cultural heritage.

From an archaeological perspective, the effects of fill, geotextiles, and other materials utilized in the formal burial of archaeological sites might also be reexamined. Computer models and simulations and/or experimental archaeology might provide pertinent information to facilitate discussions with the state historic preservation specialists in the hope of developing new mitigation strategies. In-place preservation of archaeological sites at this point in time might afford the opportunity for cultural resource professionals to assimilate the available information and encourage the development of new or revised research questions. Furthermore, in-place preservation of archaeological sites could save sufficient numbers of these endangered resources for future investigations when methods of analyzing data and retrieval of vital fragments of our past may be better developed.

Alternative mitigation measures for historic architectural properties in light of engineering and funding considerations also warrant further scrutiny. AASHTO standards and guidelines are often used to support recommendations to replace a bridge rather than to rehabilitate the structure in order to attain the level of design and/or operational engineering that is currently considered to be acceptable. The future consideration of alternatives should likely include an evaluation of the level of success of marketing programs for the sale and relocation of historic properties and the possibilities of establishing relocation and adaptive re-use funds for historic properties related to proposed transportation projects.

Finally, the enhancement of public involvement and educational/interpretive programs demands further attention. The majority of transportation projects are funded with public monies, yet few citizens are aware of the results of cultural resource investigations or the value of these endangered resources. A more structured program of public outreach appears to be crucial to the success rates of future transportation projects. It may be appropriate to establish funding line items or trust funds for public outreach programs such as the development of pamphlets, videos, posters, lectures, curriculum packages, or other educational or interpretive programs.

In summary, our nation's cultural heritage includes a continually diminishing number of nonrenewable resources that without creative planning and application of new technologies will be lost forever. As we approach the twenty-first century, we need to continue to learn from the past and anticipate the future.

RESEARCH NEEDS STATEMENTS

Title: Review and Improvement of the Existing Processes and Procedures for Evaluating Cultural Resource Significance

Problem Statement: One of the most important and critical problems faced by state and local transportation agencies is how to determine the significance of cultural resources (including but not limited to archeological sites, historic structures, traditional cultures, and cultural/historical landscapes). Significance refers to cultural resources that meet National Register of Historic Places criteria, state register criteria, and local and tribal designations. How resource significance is evaluated has direct and measurable effects on the scope, design, scheduling, and cost of transportation projects, as well as the protection of cultural resources.

Currently, the processes for evaluating significance are performed on a piecemeal basis and are generally done within the limited context of specific transportation projects. Decisions on significance are often made without reference to previous work or existing information, and are frequently based on out-of-date information about the location, nature, significance, and treatment of cultural resources within a given area. There is also a perception by transportation officials that cultural resource specialists consider everything to be significant, resulting in the inventory, evaluation, and treatment of resources in a redundant fashion. This is a problem which involves state and local programs. Numerous professional associations, academic institutions, and state and federal agencies are finding that the use of data base management systems and the generation of useful contexts and syntheses are very helpful tools to assess cultural resource significance. However, this has often been done on a local basis using highly variable techniques and tools, ranging from simple paper files to Geographic Information Systems. Most transportation officials are unaware of what has been accomplished by these groups. The usefulness and cost effectiveness of these efforts has not been fully assessed in the context of transportation projects.

Transportation professionals are being called upon to make better decisions on how to more efficiently manage funds and resources. In order to make better decisions about cultural resources, a review is needed of: 1) existing database management systems and 2) the mechanisms for generating cultural contexts employed by tribal, state, and federal agencies. These systems and mechanisms need to be evaluated for their ability to quickly and efficiently access existing information on cultural resources and to provide a framework in which resources are evaluated (i.e. the cultural context) and redundancies are identified. By addressing these needs, transportation officials will be able to make informed choices about database management approaches and define the most appropriate process for generating useful contexts leading to better determinations of resource significance. Furthermore, this will enable transportation officials to focus time and money on those cultural resources that are of value to the many communities served by the transportation project.

Proposed Research: (1) Conduct a national review of database management systems used and being developed by state and local agencies that collect and process cultural resource information. (2) Conduct a nationwide review of the processes that have been used to generate cultural contexts and/or syntheses that have been determined helpful by transportation agencies. These processes include agency overviews, resource management plans, state plans generated by SHPOs, tribal preservation plans, and local government preservation plans. (3) Evaluate database management systems in terms of their ability to provide access to usable data. (4) Evaluate the processes used to generate cultural contexts and syntheses and whether these contexts have been usable to assess resource significance. (5) Make recommendations as to best practices for database management systems and generation of cultural contexts and syntheses. (6) Compile these findings into a comprehensive report for distribution

to transportation officials and cultural resources professionals for review. This report will provide recommendations for implementation of best practices.

Duration: 24 months
Cost: $400,000.00

Title: Identification of Techniques to Improve Public/Private Dialogue Regarding Impacts and Benefits of Transportation Projects on Cultural Resources

Problem Statement: There is a need to have a dialogue with the public on how to incorporate their cultural/historical values into the project planning and development. This will result in an early identification of potential public controversy or fatal flaws over cultural resources that could cause project development schedule delays. In addition, the study of cultural resources (including, but not limited to: archeological sites, traditional cultures, historic structures and cultural historic landscapes) in transportation project development often is viewed as technical information to be included in the NEPA document as the end-product. This results in a lack of direct benefits to the public on what has been learned from the cultural resource studies they have funded. The information gained from cultural resource studies needs to be articulated in non-technical terms and shared with the community in ways that will not threaten the sensitivity of the cultural resources.

Proposed Research: (1) Survey the state Departments of Transportation and federal agencies to gather examples of standard and innovative approaches where cultural/historical values of the community have been incorporated into project development; (2) Survey the state Departments of Transportation and federal agencies to gather examples of standard and innovative approaches in sharing cultural resource information with the community that directly benefits both the resources and the community; (3) Evaluate the effectiveness of these approaches in terms of :

- community satisfaction;
- educational benefits;
- economic benefits; and
- overall time-cost factors in project development.

(4) Provide recommendations and guidelines on "Best Practices" that will maximize public participation into how the transportation project best serves the cultural/historical values of the community; disseminate the public benefits of cultural survey information; and streamline the Section 106 process in transportation project development by early identification and consideration of cultural resources.

Duration: 18 months
Cost: $350,000

Title: How Do You Successfully Incorporate 550 Tribal Nations in an Existing Transportation Network which Recognizes the Value of Culture and Respects Sovereign Authority?

Problem Statement: Cultural resources (including but not limited to: archeological sites, traditional cultures, historic structures, and cultural/historic landscapes) are critical elements of aesthetic value for the scenic byways program, heritage areas, tourism initiatives, and corridor management plans. The traditional cultures that exist in this country transcend the idea of historic places or landscapes and are inherent in the vital communities identified by sovereign American Indian and Alaskan Native Nations. They, as well as other traditional cultures, should be recognized as assets and incorporated in the transportation process.

With over 550 federally recognized tribal nations from the east coast to the west, incorporation of Traditional Cultures into the context of cultural resources for use by transportation professionals and communities is problematic. This includes: transportation planning, impact analysis, public involvement, corridor preservation/development, and economic enhancement considerations (tourism and trade). Currently Sovereign Tribal Nations are not included in transportation decision making. The status that Sovereign Tribal Nations enjoy and the legal implications of that sovereignty are often overlooked by transportation professionals. Traditionally, transportation officials have worked with the Department of Interior (DOI), Bureau of Indian Affairs (BIA) in transportation planning and project implementation. However, tribal nations are identified under the Constitution as sovereign, with authority to develop and implement transportation infrastructure. ISTEA recognizes the status of tribal governments in various programs including: Statewide Planning, Transportation Enhancements, Scenic Byways, Local Technical Assistance Program, and the Indian Reservation Road Program. Thus Tribal Governments are key decision makers as well as the BIA, and State Highway Administrations (SHAs) and USDOT.

Proposed Research: Examine what has been accomplished with respect to transportation partnerships which include tribal governments since ISTEA.

- What are the Best Practices for incorporating Traditional Cultures in the transportation planning, impact analysis, public involvement, corridor preservation/development, and economic enhancement considerations (tourism and trade).
- How many states have established a partnership with tribal governments for decision making?
- Have tribal governments been involved in transportation decision making?
- Have tribes been informed of their role in transportation planning and project implementation?
- Have any tribes defined a role for themselves?
- What role have tribes had as a partner in transportation related tourism planning?

A report reflecting the results of the study will include recommendations and guidance to implement Best Practices. The report will to be distributed to SHAs, FHWA, Tribal governments, State Departments of tourism, Federal Land Agencies, Scenic Byways organizations, BIA, Metropolitan Planning Organizations, Regional Planning Commissions, etc.

Duration: 24 months
Cost: $400,000

Title: Development of Effects Assessment Guidance

Problem Statement: For cultural resources (including, but not limited to, archaeological sites, traditional cultures, historic structures, and cultural/historic landscapes), effects assessment is neither well understood by the transportation agencies, the public or the State Historic Preservation Officers (SHPOs) nor consistently applied to all transportation projects. The consequences of this lack of understanding and consistent application of effects assessment are: difficulty in assessing the full range of effects, misunderstanding by the public of the costs and benefits of transportation projects, project delays, and ultimately, the potential for projects to not adequately protect cultural resources. Despite regulatory guidance by the Advisory Council on Historic Preservation (ACHP) and the USDOT, there is a critical need for a better and wider understanding of the effect assessment process as it specifically applies to cultural resources in order to ensure both the adequate consideration of the full range of effects on cultural resources, and the development of transportation projects that balance the long term needs of cultural resources, transportation and affected communities.

Assessment of the effects of a proposed transportation project is at the core of the comprehensive environmental analysis required to shape a project that satisfies transportation needs and ensures maximum protection for cultural resources. For cultural resources, the effects assessment begins with the delineation of the Area of Potential Effect (APE), moves through the identification of significant cultural resources, and evaluates effects on cultural resources with the goal of avoiding or minimizing adverse effects. Direct effects are most easily and consistently evaluated. Indirect, secondary, cumulative, and induced effects are not well defined and therefore, not consistently considered as part of the effects assessment. In fact, guidance as to how to identify and apply the full range of project effects is lacking. The assessment of effects under Section 106 of the National Historic Preservation Act (NHPA) is distinctly different from the evaluation of project impacts under Section 4(f) of the US DOT Act. Coordination of these two processes is another potentially problematic issue deserving review. Additionally, community involvement in the effects assessment process is not uniform from agency to agency and state to state.

Proposed Research: I. Review of planning, environmental analysis, and preservation literature discussing effects assessments as related to transportation projects and identification of gaps in the available knowledge.

II. Survey of federal Department of Transportation agencies (FHWA, FTA, FAA), state Departments of Transportation, SHPOs, Metropolitan Planning Organizations (MPOs), Regional Planning Commissions (RPCs) and Tribal Governments' guidelines and experiences regarding delineation of the APE, identification and involvement of the affected community, application of effects assessments and their coordination under both Section 106 and Section 4(f), and identification of particularly successful or problematic projects.

III. Identification of transportation project types that would involve the application of the full range of effects assessments (direct, indirect, cumulative, and secondary), such as light rail transit (LRT), highway bypasses, airport expansions, etc.

IV. Selection, review and analysis of specific case studies of completed projects of the type identified in III to evaluate the validity and efficacy of the community involvement and effects assessments on cultural resources.

V. Development of recommendations and guidance to be used in the process of assessing effects on different types of transportation projects. Preparation of draft report for review and comment. Incorporation of comments and distribution of final report to appropriate public agencies and interested professionals.

Duration: 12 - 18 months

Cost: $250,000 - $300,000

Title: Evaluate Efficiency of "Innovative" vs. "Standard" Cultural Resource Mitigations

Problem Statement: Over the past 30 years a set of a few standardized mitigation measures for impacts to standing structures and archaeological sites have been developed and relied upon by cultural resource professional and transportation officials. These standard mitigation measures generally include archaeological data recovery and detailed architectural mitigation measures typified by Historic American Buildings Surveys (HABS) or Historic American Engineering Record Surveys (HAER). In many cases, these mitigation measures are not tailored to the extent of the project impact or the importance of the resource. These standard mitigations frequently result in the expenditure of time and funds out of proportion to their potential benefit to the public or the professional community. Innovative mitigation measures may be more appropriate for achieving preservation and project goals for many transportation projects.

Proposed Research: A survey of alternative mitigation strategies will be undertaken. The results of the study will have wide applicability for transportation projects throughout the country. Communication with professional cultural resource managers indicates that creative solutions more closely tailored to the needs of the projects and resources have been implemented in a limited number of cases. One of the goals of the proposed research is to evaluate these "solutions" for their wider applicability.

A survey of the Advisory Council (ACHP), 50 state SHPOs and DOTs will be conducted to collect case studies of alternative mitigations that have been successfully/unsuccessfully employed on cultural resources. The case studies will be evaluated in terms of the efficiency of time and cost, the appropriateness of scale and wider applicability of the technique. Surveys of other environmental specialists and agencies will be conducted to collect mitigation concepts employed by them that potentially could be applied to cultural resource issues.

Preliminary research has indicated that innovative avenues that might be profitably explored for archaeological mitigations could include but not be limited to: resource banking, off-site mitigation, and in-place preservation (e.g., site burial). Innovative mitigations for architectural resources could include but not be limited to: preservation easements, land use planning, and adaptive reuse.

The case studies collected and the techniques identified will be synthesized and evaluated. The results of the evaluations will be compiled into a report providing preliminary recommendations for the implementation of innovative mitigations. These reports will be disseminated to focus groups for their review and comment. The comments will be incorporated into a final report.

Duration: 18 - 24 months
Cost: $360,000

Title: Identification and Recommendation of Roadway Design Considerations That Can Be Modified and Applied in Specially Designated Corridors

Problem Statement: Transportation corridors are often within areas that offer cultural, historic, or scenic qualities. These qualities are many times strongly embraced and valued by communities and society in general. The roadways within these corridors are recognized for this value by receiving an associated designation. These designations include:

- Scenic and Historic Byways;
- Scenic and Historic Highways;
- Scenic and Historic Parkways; and
- Scenic and Historic Roads.

Other designations with similar issues include:

- Scenic Parkways;
- Scenic Byways;
- Scenic Highways;
- Scenic Backways;
- BLM Backways;
- Forest Service Scenic Byways;
- NPS Parkways;
- FHWA: National Scenic Byways;
- All American Roads; and
- Locally and Tribally Designated Roads.

As these facilities receive more use they may require modifications to respond to the changes in the level of service and to ensure user safety. These improvements are sometimes detrimental to the qualities valued within the corridor. There is a need to identify those aspects of roadway reconstmction that are potentially most detrimental to corridor resources and consider criteria that take into account the cultural, historic, and scenic qualities. These special criteria would provide a more compatible integration with corridor resources while still providing an appropriate expectation of safety improvements.

Proposed Research: 1. Identify and reference ongoing work which identifies critical cultural, historic and scenic elements.

2. Perform surveys to establish driver expectation of the resource experience.

3. Perform surveys to establish community and resident expectations of maintaining the corridor qualities.

4. Identify, collect and examine previous research, case studies, and state programs that will aid in compiling a list of the most critical criteria. Potential criteria that may have the most influence on corridor compatibility include those affecting roadway width, shoulder treatments, materials for roadside appurtenances, grading and drainage approaches and solutions, and tree protection and mitigation.

5. Determine trade-offs in degree of facility improvement to roadside resource loss for each of the criteria applications.

6. Recommend an appropriate new range of application for the examined criteria which will provide an opportunity for a more balanced implementation of driver and resident expectations and roadway improvements within these sensitive corridors.

Duration: 24 months
Cost: $300,000

ENERGY CONSERVATION, ALTERNATIVE FUELS & CLIMATE CHANGE

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BACKGROUND PAPER

Research on transportation-related energy and fuel topics in the transportation arena needs to enhance the understanding of major fuel control policies and their current effects. To set the U.S. fuel economy goals, Congress passed the Energy Policy Conservation Act in the 1970's. This was followed by a phase-in Corporate Average Fuel Economy (CAFE) program with stringent fuel economy standards for fuel mileage uses beginning with 1975 vehicle models as proposed by the National Highway Traffic Safety Administration (NHTSA) in conjunction with the U.S. Department of Energy (DOE), through which the national fuel control and energy conservation policies have been established. As a new emphasis, the 1990 Clean Air Act Amendments (CAAA) require the federal government to regulate and control the fuel used for cars, trucks, and buses to reduce emissions of carbon monoxide, ozone precursors such as volatile organic compounds (VOC) and NOx, particulates, and air toxics, as well as to reinforce the continued regulation of lead in gasoline, sulfur content in diesel, and the volatility of gasoline, in compliance with previous requirements in the 1970s and 1980s. To reduce the emissions of particulate matter (PM) from trucks and buses, the U.S. Environmental Protection Agency (EPA) issued regulations to limit the sulfur in diesel fuel. In areas exceeding the National Ambient Air Quality Standards (NAAQS), the EPA also limits the volatility of gasoline to reduce ozone pollution, and requested states to provide plans that might include oxygenated fuel, reformulated fuel, and alternative fuel programs in non-attainment areas. A typical alternative fuel is defined as any fuel, such as reformulated gasoline, methanol, ethanol or other alcohols, natural gas, diesel, liquefied petroleum gas, or electricity, that meets clean fuel requirements. While serving as a measure to reduce the environmental threats, alternative fuels should also match with the general energy conservation goals to ensure that the supply and use of new energy sources are sufficient, reliable and economically viable. The interaction between fuel economy policies and emissions reduction requirements has became a major area of interest.

A series of studies for evaluating the effects of current energy conservation and fuel practices on our transportation system, and for assessing the feasibility of improvements, should be progressed. The research work should take national and regional impacts of various fuel requirements into account, and define the fuel economy effectiveness of oxygenated fuel, reformulated gasoline, low-sulfur diesel, and other alternative fuels.

The future approach of energy and fuel uses in transportation facilities is to follow new requirements to control motor vehicle emissions while keeping mileage economy policies effective. With the establishment of clean fuel vehicle programs, manufacturers may not release for sale any new fuels or new additives without receiving approval from the EPA. Clean fuels are classified simply by exhaust emission performance standards and result in substantially lower tailpipe emissions. Two major applications are expected in clean fuel programs: alternative fuels and reformulated gasolines. While the reformulated fuel is currently the market-favored option, a promising alternative fuel for motor vehicles appears to be methanol. Methanol is a liquid, high octane, low volatility fuel, and more energy efficient than gasoline. However, the health effect, the cost, and the risk of fuel tank explosions with methanol need to be explored in greater detail. Compressed natural gas (CNG) is another viable option under investigation. The biggest advantage of using CNG is the

fuel cost saving, if proper storage, transport, and greenhouse gas control are applied to actual operation when CNG is under global use. How to select an appropriate alternative fuel in various regions that will meet emission requirements, satisfy mileage standards set for vehicles, and fit cost-effectiveness criteria is a major concern in the near future.

From both an energy conservation and clean environment point of view, another important issue related to fuel consumption is the prevention and minimization of hydrocarbon evaporative emissions in fuel dispensing operations, in truck loading for distribution, and in fuel retailing facilities. Evaporative hydrocarbons or volatile organic compounds will be emitted from gasoline dispensing and retailing facilities when storage or loading tanks are filled with C_4 and C_5 (paraffins and olefins) that are photochemically reactive as precursors to oxidants. Evaporative emissions released from trucks and motor vehicles originate from basic components of the vehicle's fuel system - the fuel tank and the vehicle carburetor. Evaporative emissions from the fuel tank, known as diurnal losses, occur as the gasoline vapors expand in the fuel tank in response to ambient temperature increases. Other vehicle evaporative emissions, known as hot-soak losses, occur just after the engine is turned off, when residential engine heat causes the evaporation of the fuel remaining in the vehicle carburetor bowl and fuel lines. Evaporative emissions are dependent on fuel volatility, temperature, and operating practices. The U.S. EPA estimates that evaporative emissions from fuel handling units account for 8 percent of the total hydrocarbon inventory nationwide. Therefore, developing a gasoline vapor recovery or balance system is a new area to explore. Types of vapor recovery systems include compression-refrigeration-absorption (CRA), straight refrigeration (RF), and thermal oxidation. The CRA system is based on the absorption of gasoline vapors under pressure with chilled gasoline from storage. The RF system is based on the condensation of gasoline vapors by refrigeration at atmosphere pressure. Each of these systems needs appropriate research to determine recommended practices and applicable codes or limits.

Besides controlling fuel economy and emissions, a task of developing alternative fuels and vehicles that are powered by energy sources other than gasoline to reduce the amounts of greenhouse gases (CO_2 and CH_4) and other environmental threats is also essential. One challenge for this task is to find an alternative fuel by changing fuel mix (i.e., using fuel with more hydrogen and less carbon) to reduce the amount of undesirable gases from vehicles.

To provide possible solutions to the current and future concerns, suggested research areas should focus on a variety of issues, including the following: gasoline marketing regulatory strategies; energy conservation goals for reliability and economy of alternative fuels; state-of-the-art practices in handling liquid fuels with environmental considerations; effects of transportation improvement programs on the environment; use of improved gas mileage fuels; costs associated with meeting both CAFE and CAAA requirements through the use of alternative fuels; impact of refueling emission regulations on energy conservation; toxics aspects of alternative fuels; application of CNG; evaluation of health effects associated with use of alternative fuels and additives; study of alternative fuel refueling infrastructure development; pricing mechanisms for transport fuels; impact study of market-based regulations on alternative fuels demand; the overall role of alternative fuels in reducing mobile source emissions; feasibility of international cooperation to promote alternative fuel vehicles; environmental consideration and energy conservation of fuel handling units; effect of alternative fuels on CAFE mileage standards; cost analysis of gasoline vapor recovery systems; best options for selecting alternative fuels for reducing greenhouse gases; potential evaporative emissions from alternative fuels; devices to trap gasoline vapors from engine and fuel systems; and recommended practices for installation and operation of fuel handling units to reduce evaporative emissions.

Experts and the public have become concerned about a previously unrecognized environmental threat, the greenhouse effect (global warming). The relationship between this threat and air emissions from transportation is a new targeted area for research. Climate observation shows that the human-induced climate change has been caused by changing composition of the atmosphere and increasing air pollutants. As selected for emphasis, carbon dioxide (CO_2) and methane (CH_4) are increasing in the atmosphere and play a role in governing the global climate by absorbing and re-emitting infrared radiation that would otherwise escape directly to space, thereby trapping heat. These heat-trapping gases keep the surface warmer than it would otherwise be. In addition, because ozone also acts as a greenhouse gas, an increase in ozone concentration in the free troposphere will have climatic consequences. The projected climate changes are further enhanced by other air pollution problems created by people, such as acid

precipitation which involves a complex pattern of emission sources of SO_2 leading to complicated chemical and physical reactions in the atmosphere.

To document these forward-thinking study areas, many new topics need to be explored such as: the impact on greenhouse gases of reducing CO_2 through the use of alternative fuels; model development for estimating CO_2 from motor vehicles based on fuel consumption; and feasibility of setting international greenhouse gases standards (CO_2, CH_4) and their potential impacts on the world economy.

RESEARCH NEEDS STATEMENTS

Title: Implications of Global Motorization for Energy Use and the Environment

Problem Statement: In 1950, three-fourths of the world's motor vehicles could be found in the United States. Today, less than half are located in the U.S. Moreover, while the U.S. vehicle fleet has been growing at a rate of 1% over the past 20 years, vehicle populations in Europe and Japan have been increasing at 2-3% per year, and those in the rest of the world have been expanding at twice that rate. The potential for motorization of transport in nations of the former Soviet Union, China, and the rest of the developing world is enormous.

Growing global motorization is already creating staggering pollution and congestion problems in cities of the developing world. Rapid motorization outside the U.S., together with the end of vehicle fuel economy gains within the U.S. are putting ever greater pressure on the world's geographically concentrated oil resources. Since 1970, transportation has been the only sector whose worldwide oil demand has increased. Continued reliance on fossil fuels also results in increasing emissions of greenhouse gases. All of these forces are creating intensifying stimuli for technological, institutional and behavioral change.

The trend toward global motorization of transport is certain to pose significant new problems for transportation systems in all countries, developed and developing. Innovative solutions, often involving international cooperation and coordination will be required.

Proposed Research: This study will make a strategic assessment of the implications of rapid motorization of the world's transport systems for the future of transportation. A conference of national and international experts drawn from government, industry, academia, and nongovernmental organizations, will consider implications of global motorization for the world's natural resources and its environment. The conference will specifically address what the implications of a transition to a sustainable global transport system would be for developed and developing countries. Invited, peer-reviewed papers will be presented and discussed. The papers will be subsequently published in the form of a book.

- Task 1. Assemble an organizing panel of experts.
- Task 2. Invite participation of cosponsors (e.g., SAE, the World Bank, DOE, ECMT, OECD, etc.).
- Task 3. Plan the conference (date, place, sessions, participants, solicit papers).
- Task 4. Review papers.
- Task 5. Hold conference, revise and resubmit papers.
- Task 6. Publish proceedings.

Cost: $150,000 - $250,000
Duration: 18 months

Title: Alternative Fuel and Super Efficient Vehicle Market Penetration and Its Implications for Greenhouse Gas (GHG) Emissions, and Regional and National Macroeconomic Effects

Problem Statement: Current models that have been used to measure the energy and climate change implications of high market penetration of alternative fuels and super efficient vehicles do not capture the effects upon macroeconomic factors such as interest rates, GNP, employment, nor do they capture the change that will be required in resources and the mix and level of economic activities. Although impacts of fuel prices upon energy markets and their small marginal fuel price impacts upon macroeconomic factors have been studied, the effects upon the capital markets that would have to supply the extensive capital for GHG scenarios, including rapid AFV and PNGV market penetration, and accompanying massive infrastructural requirements, have not been examined.

Proposed Research: Because only cursory attempts have been made to measure the macroeconomic effects via assumed simplistic multipliers/elasticities or calculations, a fully integrated approach is required to capture all of the financial, material, human and capital resource, and energy flows through the economy. It is necessary to use an existing fully integrated model (such as the National Energy Modeling System at DOE/EIA, DRI, GRI, etc.)

which includes: a) all supply (oil, natural gas, coal, electricity, renewables) and demand (residential, commercial, industrial, and transportation) energy sectors, b) all financial markets and institutions, and c) the full representation of the economy on a regional level.

The transportation model chosen for use in this analysis must be capable of : a) accounting for the potential market penetration through vehicle choice of several AFV technologies (flex/bi-fuel/hybrid and dedicated, alcohol based, CNG, LPG, electric, fuel cell, and gas turbine) of which one may be a super efficient vehicle type; b) measuring the impacts of fuel prices and macroeconomic factors on travel and efficiency improvements with their marginal costs; c) forecasting future AFV regional sales based on AFV and super efficient vehicle characterizations pertinent to the vehicle consumer choice and AFV regulations; d) accounting for the effect of various vehicle attributes upon vehicle price; and e) estimating the GHG emission resulting from forecasted fuel consumption levels by fuel type. Models capable of making such calculations, such as the EIA's NEMS model, already exist and should be used in this study.

This research must develop procedures for measuring the infrastructural costs associated with substantial AFV or super efficient vehicle market penetration; estimating the flows of capital and changes in economic activity and consumption patterns resulting from the material, physical capital, and human resource flows required to meet the AFV/PNGV scenarios. This may be done by means of the use of an input/output matrix model or other appropriate method.

The outputs of this model should describe the key changes in the structure of the economy and the changes in the resources (human, capital, and physical) that will be required for a massive change in transportation fuels and vehicle technology.

Cost: $350,000 - $450,000
Duration: 2 Years

Title: Consequences of Alternative Highway Pricing and Financing Systems for 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 that are not borne individually or collectively by 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. While 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, and could thus logically be imposed on a per-trip or per-mile basis, some cost elements clearly fall into this category.

Rapid advances in microelectronic technology will in the near future permit the deployment of non-intrusive, 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 the substitution of new forms of pricing and the likely levels of such charges, 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 VMT 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 (a) each component of costs now covered by motor fuel or other transportation-related taxes; (b) each motorist-borne cost component now paid in fixed increments; and (c) each empirically significant external cost element associated with highway travel. At least one of the alternatives should represent an attempt to maximize the social wel-

fare of the highway transport system by economically efficient pricing.

(5) Use available behavioral theories and empirical evidence 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 VMT, vehicle and fleet fuel economy, trip characteristics (frequency, timing, length, etc.), density of development, motor fuel consumption, and emissions of criteria pollutants and greenhouse gases.

Cost: $150,000 - $200,000
Duration: 9-12 months

Title: Preparing a Public Outreach Toolkit to Promote Options to Reduce Personal Transportation Energy Consumption and Greenhouse Gas Emissions

Problem Statement: States, localities, and metropolitan areas can assist the public in reducing their transportation energy usage and greenhouse gas emissions through information about AFV, TDM, transit and other options. As the world population continues to increase and vehicle usage and VMT continues to grow, diverse approaches to sustaining our environment must be found. It is imperative that the U.S. seek to efficiently utilize limited resources. Energy consumption continues to expand as does the production of greeenhouse gases. As seen with programs to increase household and community recycling, subtle changes in individual behavior can yield dramatic changes in overall results. It is imperative that we consider the individual role in the consumption of energy for personal transportation. Changing individual behavior can 1) help the U.S. and the world reduce greenhouse gas emissions, 2) reduce U.S. dependence on foreign oil, and 3) create a more sustainable future.

Proposed Research: This study would proceed in four phases with the end result being a toolkit of information on options which could be utilized to inform the public on the issues of AFV, TDM, transit, and other options to reduce personal transportation energy consumption.

The first phase would include two tasks. In task 1 a "resource document/guidebook" summarizing available research on various options to reduce personal transportation energy consumption would be prepared. This document would summarize briefly each available option, presenting information on cost of start-up, cost of operation, ease of implementation, energy benefits, etc. At a minimum, the options to be addressed would include: available AFVs, neighborhood cars, station cars, energy conservation awareness training, etc. The second task of the first phase would assess the public's knowledge of potential options. Past experience and success with various options (such as AFVs, station cars, and neighborhood cars) would be researched and presented in the "resource document/guidebook."

Phase 2: In the second phase an "outreach sourcebook" would be prepared. This phase would synthesize available information on public outreach and marketing tools and methods. Readily available strategies and approaches would briefly be presented in the "sourcebook." This document would provide details on which strategies have proven successful in the past with diverse or divergent audiences. Methods which may be assessed include: driver education campaigns, in-school awareness training, videos, one-time incentives, employer sponsored programs, and other media approaches. A diversity of methods should be presented so that all types of groups can be reached, including different income levels, races, ages, and genders.

Phase 3: In the third phase a pilot application of the public outreach education effort will be undertaken. Six to ten interested participant locations/entities will be selected to receive some financial assistance and support in implementing a particular aspect of the public outreach campaign. The selected participants should be geographically diverse and representative of the various needs and demands of the U.S. populace. Modules should be selected that represent the potentially different needs of income levels, races, ages, and genders. Examples of modules which should be tested in the various participant locations include: a) AFV information campaign, b) neighborhood cars, c) station cars, d) driver education and awareness program. Modules should strive to represent the diversity of situations in the U.S. At least one participant / module should be representative of rural concerns. At least one participant / module should be representative of non-commuter concerns. Selection of modules should focus on selecting the most innovative, less well-known and less explored option for reducing personal transportation energy consumption. The focus of the pilot participation modules will be to gather firsthand implementation experience from which other localities may benefit.

These pilot efforts will be assisted by the documents prepared in phases 1 and 2 of this research effort. In addi-

tion, the pilot participants will provide useful insight and feedback into the products prepared in phases 1 and 2. As implementation of the pilot projects progresses, the efforts will be evaluated for feasibility of replication elsewhere.

Phase 4: The fourth and final phase will prepare a toolkit. The toolkit will include, but not be limited to: a) resource document of options, b) outreach sourcebook, c) case study implementation analyses and examples, and d) recommendations for utilization and replication. The toolkit will be distributed broadly to state, local and metropolitan area partners.

Cost: $325,000
Duration: 24 months

Title: Information to Support Innovative Planning to Improve the Energy Efficiency of Goods Movement

Problem Statement: The overall energy intensity of U.S. freight transport, measured in energy use per ton-mile, has not changed in 25 years. Trucks consume most of that energy, about 5 quads of energy per year, or about one-third that of passenger cars. Heavy duty truck fuel efficiency gains have lagged well behind those of passenger cars over the past two decades. This is due, in part, to the generally greater efficiency of HDV compared to LDV in moving mass achieved prior to the energy crisis of the 1970s and 1980s. The improvement in HDV fuel efficiency has stemmed from the increased use of higher efficiency diesel engines and other fuel efficient technologies. Significantly improving freight energy efficiency is likely to demand novel, innovative strategies for freight systems and major infrastructure investments by government and the transport industry. Transportation and environmental planners at federal, state and local agencies face a substantial challenge in incorporating heavy duty truck activity in their transportation plans. This results from a severe lack of data specific to heavy duty truck operations and use.

HDV's are a very visible source of urban congestion as a result of their imposing size, the lack of 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 Truck Inventory and Use Survey (TIUS) and the recently completed Commodity Flow Survey (CFS) provide useful data on national trends in goods movement and truck 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 HDVs.

A lack of information concerning the movement of goods throughout the economy hinders innovative planning for freight infrastructure for the 21st century. Information is required on aggregate and disaggregate activities involved in intercity and urban goods movement. 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. Such projects should increase economic efficiency and performance while reducing energy use as well as GHG and conventional emissions.

Proposed Research: *Phase I Information Collection and Needs Analysis*

Task 1 -- In this task the research team will conduct a thorough literature review on data related to freight activities and energy efficiency. Recent NCHRP, DOT and other studies will be evaluated. An annotated bibliography of the previous work will be developed.

Task 2 -- The team will meet with selected state DOT's and energy offices to establish their needs for goods movement information. Current activities undertaken by several states, FHWA and EPA to monitor truck operations with on-board devises will be included in this review. Commercial Vehicle Operations (CVO) programs included in ITS demonstration projects will also be reviewed.

Task 3 -- The team will meet with several MPO's that are expanding their coverage of freight operations in their travel demand modeling efforts to assess the value of this information in developing innovative solutions for goods movement efficiency. The use of goods movement performance measures will also be evaluated. Recent surveys on goods movement planning included in NCHRP studies and by planning associations will also be reviewed.

Task 4 -- Based on the literature review and assessment of other information collection activities, the team will develop a Phase I report that will summarize what is known about HDV and other goods movement operations and how additional information could assist planners in developing improved plans.

Task 5 -- In this task the team will develop a workplan for the conduct of the Phase II data collection efforts. The workplan 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 Prototype Development

Task 6 -- In this task the team will design a freight activity database that will provide the framework for describing activities of heavy-duty trucks and other modes. Data will 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 7 -- Select 2-3 regions/states to develop a freight information database. The selection will be based on the availability of state and local freight information such as an intermodal management plan, or an HDV emission information system. Selection will also consider the regional characteristics, types of goods moved, and other factors.

Task 8 -- Develop the regional/state freight information system for selected regions. The information incorporated will be from secondary sources and from surveys and HDV monitoring activities conducted to fill data gaps.

Task 9 -- 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 10 -- Conduct surveys and instrument vehicles as needed to fill the information system for each region. Include the information in the system and finalize the data set. Provide and demonstrate the information in each selected region.

Task 11 -- Prepare a handbook on the development of a freight information system for energy, environmental and highway planning. The handbook will identify sources of data and methods for developing local information to supplement what is known from other studies. The handbook will provide a model database, including default values for most cells. Instructions for the use of information and the calculation of project benefits will also be developed.

Task 12 -- The team will 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: $325,000
Duration: 24 months

Title: Changes in the Geography of Production Systems: Implications for Freight Energy Use

Future industrial and commercial activities will take increasing advantages of advanced control computation and communications technologies to change scale and to relocate or decentralize. This study will develop information on the changes in transportation requirements (energy use and emissions) and the new infrastructure requirements of the decentralization of business activities.

Problem Statement: The structure of US cities has changed significantly in the last century as a result of the availability of public transit and the automobile. Equally significant, but less well understood changes may be induced as increasingly effective use is made of advanced control, computer, and communications technologies. Companies will move to locations which improve their operations and the distribution and sale of products and services

The first stage of this process has been the creation of the ring cities - suburbs. Improved controls (manufacturing processes) and communications increase the options for plant location and scale. Companies are decentralizing. Many have elected to move to green field sites or smaller communities. This trend will accelerate as existing facilities become obsolete and are phased out.

The second stage will include relocation to smaller (frequently rural) communities. The computer communication "revolution" makes it possible for companies to be located almost anywhere. This is already starting. An engineering group in the mountains of Colorado is designing parts for a company in Detroit. A small office in the Caribbean is processing paper for an American credit card company.

These developments will lead to changes in the nature of freight services. It is expected that there will be smaller, more frequent services with increased use of trucks - energy consumption, emissions and road damage. To some extent these increases may be offset if the relocation of facilities is to locations which offer better access to markets.

The potential forcing factors include: 1) Access to markets; 2) Lower taxation; 3) Changing scale of facilities (human scale vs. traditional economies size); 4) Avoidance of historical pollution problems (brown field start-ups); and 5) Access to an appropriate work force

The necessary requirements for relocation include: 1) Potential for improved profits; 2) Attractive land sites (for jobs and employees); 3) Development of new processes and procedures which permit changes in scale of the operations; 4) Ability to amortize existing investments; and 5) Access to appropriate transportation (road, rail, air).

The movement from transitional urban areas will impact the requirements for transportation (people and goods), and, as a consequence, the requirements for use of the transportation infrastructure. New roads (and railroads) may be required in areas where there now is little if any commercial activity. Existing roads in these areas may be overloaded. Distributed 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.

Proposed Research: 1. Identify the kinds of industries and businesses that have the potential to relocate, considering existing investments and access to customers or clients.

2. Identify manufacturing process and operational improvements that may be used more efficiently in new locations, such as changes in the understanding of the economics of scale.
3. Identify the incentives and constraints to dispersion of major employers.
4. Project the dispersion of employment opportunities to suburbs, smaller cites, and other locations by time and type of location.
5. Identify the induced freight requirements to service the businesses and supporting communities (food, goods, etc.).
7. Estimate the impact on existing cites, reductions in jobs, reduction in congestion, etc.
8. Estimate the impact on transportation requirements, person and goods movements.
9. Prepare an overview of the national impacts on energy consumption and emissions that may be provided (or caused) by the decentralization of business activities. Estimate confidence levels and potential time periods over which these changes may occur.

The project will be directed at the needs for freight movement, however it will also provide information on the potential movement of populations from existing cities. If the jobs are there residences will follow.

Cost: $350,000 - $450,000
Duration: 18 months

ENVIRONMENTAL REVIEW PROCESS

WORK GROUP PARTICIPANTS

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BACKGROUND PAPER

Environmental considerations have been and remain critical factors in the development and approval process of transportation projects throughout the country. Since the passage of the National Environmental Policy Review Act of 1969 (NEPA) and other related legislation such as the Clean Water Act and the Clean Air Act Amendments of 1990, transportation agencies have been obligated to put transportation projects through an often rigorous and time-consuming environmental review process. As a result, there has been an increased awareness and interest in identifying methods and procedures to expedite and standardize the environmental review process among transportation agencies, to make the process part of the early stages of project development and design, and to do so in a more cost-effective manner.

Several environmental issues have come to the forefront in the 1990s that demand increased consideration. These issues broaden the scope of environmental review, raise broader concerns for the environmental review process, and necessitate consideration of environmental factors relatively early in the project planning and development stage. As a result, these issues require new approaches within the environmental review process, and corresponding guidance and training for implementers.

The passage of the Surface Transportation Act and the Intermodal Surface Transportation Efficiency Act (ISTEA) provided for changes in the manner that projects are planned and programmed, including an expanded role of the Metropolitan Planning Organizations (MPOs), particularly in urban regions. The ISTEA legislation and implementing regulations created a process known as the Major Metropolitan Transportation Investment Study (MIS), which serves as a mechanism to evaluate the effectiveness of alternate transportation investments. Under ISTEA, MISs are required to identify and ultimately improve the effectiveness of investments in regional transportation systems in urbanized areas. While environmental review is one aspect of an MIS, the appropriate level of environmental review within this process requires further study, as does a determination of the appropriate and most effective mechanism for integration of the MIS process with the environmental review process pursuant to NEPA.

Recent studies, including a July 1995 TRB published paper entitled *Integrating Major Metropolitan Transportation Investment Study Process with National Environmental Policy Act Process*, are an early attempt to provide a suitable mechanism for integrating the MIS into the overall NEPA review process. In addition, the upcoming NCHRP Project 8-34, *Major Investment Studies: Process Development Including Coordination with NEPA Requirements*, is further intended to provide guidance on integrating MIS with the NEPA process. Meanwhile, the Federal Highway Administration and the Federal Transit Administration are in the process of revising 23 CFR 771 environmental regulations to incorporate ISTEA and other provisions and research into NEPA, following which a new technical advisory to provide guidance to transportation agencies in implementing these regulations is proposed. These research activities notwithstanding, there is a need for transportation research to further examine how transportation projects are evaluated under both NEPA and MIS with the following goals: identifying a process that can focus attention on the issues that are truly pertinent to decision-making; providing meaningful pub-

lic and interagency involvement in the planning of transportation improvements; working toward building a consensus on solutions to transportation problems; and reconciling various possible issues. Follow-up research through case study development should also be pursued to identify practical applications of this initiative.

The January 1993 Council on Environmental Quality publication entitled *Incorporating Biodiversity Considerations into Environmental Impact Analysis Under the National Environmental Policy Act* provided some new direction for incorporating biodiversity considerations into the overall environmental review process, while the U.S. Environmental Protection Agency's Office of Federal Activities' April 1994 publication entitled *Evaluation of Ecological Impacts from Highway Development* provided additional suggestions for incorporating biodiversity considerations into the environmental review process. Transportation research needs to further address the issue of determining how biodiversity considerations can best be assessed through the environmental review process for various types of transportation projects in various settings, for example, urban versus non-urban environments.

There is also an ever-increasing need for the transportation community to take a more aggressive role in researching how environmental justice considerations, as identified under Executive Order 12898, can best be assessed through the environmental review process for various types of transportation projects in various settings. The recently published draft document entitled *Guidance for Incorporating Environmental Justice in EPA's NEPA Compliance Analyses* by the USEPA Office of Federal Activities should serve as a basis for assessing these types of impacts under NEPA. Research should begin to focus on the success of implementation strategies and commitments for various types of projects under this initiative and the applicability of these strategies to the guidance document.

Recently, it has become apparent that indirect impacts of transportation projects can be as significant as direct impacts. Research on this issue has been initiated under the National Cooperative Highway Research Program Project 25-10, dated May 1996, entitled *Estimating the Indirect Effects of Proposed Transportation Projects*. Further research should now focus on methods to identify indirect effects and the significance of these impacts in relation to a project's purpose and need. In addition, a consensus needs to be developed by both the regulatory and transportation professionals as to the cost of adverse effects. This approach is needed to further identify the relationship between project costs and the current regulations and their requirements for avoidance and mitigation.

Recent initiatives by the Council on Environmental Quality, with the cooperation of several agencies including the Federal Highway Administration, include developing a handbook entitled *Analyzing Cumulative Effects Under the Environmental Policy Act*. As in the case of indirect effects, further research is needed to disseminate the research results of this initiative in an effective manner for placing the results into practice, as well as to monitor and test the methodology.

Transportation research in the area of environmental review will also need to focus on the mechanisms and innovations for processing major and small-scale transportation projects through the environmental review process. Methods that promote the identification of environmental issues early in the project development process should be promoted in order to limit increased project costs and time delays. The research should identify specific methods and procedures for streamlining the approach while at the same time ensuring compliance with the regulatory controls in place and ensuring continuing agency and public input.

Recent initiatives have been introduced by transportation agencies in an effort to expedite the total environmental review and approval process. These initiatives have focused on the interrelationships between the requirements of the transportation agencies and those of the various state and federal regulatory review agencies. For example, many transportation agencies have taken the initiative to develop and implement a process to integrate the NEPA and Section 404 permitting processes. Follow-up discussions through case study development should be pursued to identify the degree of success of practical applications of this initiative. Research in the area of applicable federal legislation and regulations that can be better integrated in order to expedite project approvals should also be pursued, as well as appropriate programs and methodologies for proper implementation.

Additionally, some agencies have begun to process large-scale transportation projects through the Tiered EIS process in an attempt to define a project's design and purpose and need more concisely, preserve needed corridor areas, and/or identify a preferred alternative early in the process of project development. Further research should focus on the applicability of the Tiered EIS process and its effectiveness as a planning design tool and environmental review mechanism.

Emerging technologies in model development and program management have provided new opportunities and tools for managing transportation projects and for assessing the degree of the project's potential short- and long-term environmental effects. There remains a strong need

to develop innovative methods for the rapid assessment of environmental conditions and impacts and for the identification of conditions that may require extensive design changes or alternate solutions early on in project development. This is more critical today because of limited available funds and increased competition for funding. These trends will continue and result in further competition between major transportation projects and smaller-scale projects which, for reasons of design and safety, also need to be programmed and implemented. This may result in urban transportation projects competing with projects in suburban and rural settings.

Transportation research should begin to focus on methods and strategies to assess how technological advancements in computer hardware and software can be applied to support the collection of environmental data and the assessment of impacts within the environmental review process. Among these techniques are satellite imagery processing and manipulation, visualization, interactive video, geographic information systems, management information systems and scheduling software. These technologies could ultimately serve as cost-effective tools in field surveying and the identification of environmental features that could be affected by a transportation project and that could result in a constraint to the project's development. Research needs to be expanded to identify specific program applications and methods by which these systems can reduce the soft costs in the preparation of environmental documentation and review. In addition, there is an emerging need to research how to assess the environmental effects of emerging and future technologies, some of which- for example, Intelligent Transportation Infrastructure- may not trigger environmental review under NEPA simply because there is little or no physical disturbance.

Finally, one possible initiative that deserves some research consideration is that of state-certification of the NEPA process for transportation projects. This process would be similar to the increasing trend of state environmental agencies acquiring wetland permitting functions from the U.S. Army Corps of Engineers, except it would be the State Department of Transportation acquiring NEPA implementation responsibility from FHWA. Research should focus on the practicality and feasibility of state certification and the development of standard regulations that could easily be implemented. More importantly, these analyses would serve to initiate appropriate dialogue among the various agencies and identify the approaches to be considered in establishing a standardized mechanism for future implementation.

RESEARCH NEEDS STATEMENTS

Title: Applications of Existing and Emerging Technologies in Improving the Environmental Process

Problem Statement: The process of integrating social, environmental, and economic considerations with transportation decisionmaking involves the application of multiple disciplines. Current and emerging advancements in electronics, video, radio, and computer technology provide the industry with a wide variety of potential tools to enhance this process. However, these tools are not generally integrated into the process primarily because of the lack of a clear understanding of how these technologies can be used to support the environmental mission of an agency or unit.

Proposed Research: The research would focus on evaluating the full set of current and emerging technologies to assist professionals in environmental planning, analysis, decision making, and communication. These technologies (tools) include Expert Systems, Dynamic Linkage, Virtual Design and Visualization Technology, GIS, GPS, Video, and Internet Technologies. The research would involve the following specific tasks:

- Identify current exemplary practices and applications of the tools, both nationally and internationally.
- Categorize new and existing techniques and their applicability to environmental management practices.
- Examine feasibility of implementing these techniques across the broad spectrum of transportation practices.
- Recommend integrated training programs for the utilization of these tools and techniques.

The outcome of this research effort should be a document that would highlight the applications, benefits, and costs associated with the implementation of current and emerging technologies. Below are some technologies that have been identified based on their potential to contribute to the transportation and environmental decision making processes.

Electronic Clearing House over the World Wide Web for "Transportation and the Environment"

- Offers the ability for all to access and review the most current environmental information effectively and efficiently. This would include links to sites containing research information, environmental documents (e.g., EAs and EISs), environmental legislation, regulations, policies, and guidelines.

Expert Systems

- Provide guidance and assistance through the transportation and environmental decision making process, including identification of decision stages that incorporate legal requirements and agency policy and guidance, steps in the agency processes--including planning and project development, and scheduling and costing.

Virtual Design and Visualization technology

- Offers the ability to view and experience via video and computers the design and social, environmental, and economic impacts of proposed transportation projects. Procedures for merging video and computer generated images should take into consideration the ability to produce mathematically accurate and defensible images.

Dynamic Linkage

- Allows practitioners to integrate models, reports, documents and displays associated with transportation and environmental studies effectively and efficiently. This is accomplished through dynamic links within a computerized system of interrelated elements. For example, in one application, the practitioner would no longer have to make manual changes to an environmental document because an associated change has occurred in a technical analysis.

Transportation Theater

- Offers an opportunity for all stakeholders including the public and agencies to collectively experience and interactively participate in the development process and impacts of proposed transportation projects through the use of emerging technologies such as virtual reality, GIS, CADD, and KIOSKS.

Video Environmental Documents (e.g. EIS, EA)

- Offers a paperless medium for communicating and disseminating information regarding the environmental analysis of transportation projects.

Cost: $ 180,000
Duration: 18 months

Title: The Consideration of Environmental Factors in Transportation Systems Planning

Problem Statement: ISTEA requires the consideration of environmental factors in the development of transportation systems plans. In the past, these plans have generally been developed without taking environmental impacts into consideration. Transportation projects are selected for implementation based on needs identified in the systems plan. This has created problems in that projects are being recommended that are very difficult, if not impossible, to implement because of unknown environmental consequences that could have been easily identified, considered, and possibly avoided much earlier in the planning process. At present there are no generally accepted processes and techniques for transportation planners to utilize in including environmental considerations in transportation system planning. Environmental considerations are typically addressed in an environmental document during project development and, in some cases, during corridor planning analysis. In addition to a "fatal flaw" analysis, there are some environmental considerations that are more appropriate at the systems planning level. These include such things as: purpose and need, arcawide air quality, ecosystem analysis, watershed evaluations, social and community impacts, indirect impacts, and cumulative impacts. Cost-effective macroscale analysis techniques, such as GIS applications and air quality modeling, are available for evaluating systems plans. However, these and other techniques are not widely applied in system level transportation planning. If elements of transportation systems plans are to proceed through project development to implementation, system level environmental considerations must be taken earlier in the planning process. The development of these planning techniques and procedures for applying these techniques early in system level planning are the purpose of this research.

Proposed Research: It is recommended that this problem be addressed through: (1) A synthesis of existing practices of DOTs and MPOs to determine the current practices in the consideration of environmental impacts for transportation systems planning. (2) Identification of state of the art analysis techniques and emerging technologies. (3) Evaluation of issues and obstacles for system level consideration of environmental factors. For example: institutional, legal, regulatory, technical, cost, and project management. (4) Development of methodologies and/or technologies for the consideration of environmental impacts at the macro-scale level. (5) Development of a process that can utilize these methodologies in the appropriate evaluation of environmental factors in the development of transportation systems plans.

Cost: $200,000
Duration: 2 Years

Title: Environmental Process Practices

Problem Statement: Over past years various innovations and practices have been employed by different state DOT's (and Agencies such as COE, NPS, USFS, F&WS,

etc.). The transfer of experience among the various independent practitioners does not occur in a systematic and comprehensive fashion.

Proposed Research: Document environmental practices and innovations that have been tested throughout the transportation industry in a form that would enable transportation agencies to improve their processes. With this information, recommend improved process models.

Phase 1. Survey existing practices and innovations including:

- 404 / NEPA mergers;
- Programmatic agreements and approvals (e.g., 4(f); Categorical Exclusions, Environmental Assessments, Section 106, Wetland Permits, Conformity, Noise Assessments, EIS processes, programmatic EIS's, etc.);
- Tiered EIS's;
- Interagency agreements;
- MPO / DOT planning processes;
- Environmental project management techniques;
- Tradeoffs between potentially impacted resources;
- Follow-through on environmental commitments;
- Quality assurance procedures;
- Project review / approval mechanisms;
- Systematic program-level coordination with resource agencies; and
- Post-NEPA assessments.

Survey results should detail:

- Process title;
- Problem addressed;
- Description including regulatory context;
- Points of contact for further information at both transportation and resource agencies;
- Copies or citations of applicable procedures, agreements, permits, etc.;
- Performance data including available numerical data on savings of time, money, environmental impact, paperwork, coordination, duplication, etc.; and
- Value added.

Phase 2. Report survey results.

This analysis of existing processes will include survey results together with a categorization of topic areas, process types, frequency of use among states, range of applicability among project and problem types, discussion of advantages and disadvantages of various approaches from both a resource and transportation perspective as illustrated by case studies and examples of actual permits, agreements, approvals, etc.

Phase 3. Make recommendations

Develop improved process models and best practices in cooperation with an expert panel of experienced practitioners. Recommendations should address changes to State and National practices, policies, procedures, processes, permits, agreements, standards, regulations, and law. Recommendations should be supported by information derived from the phase 2 survey as applicable.

Cost: $200,000
Duration: 2 years

Title: Transportation Environmental Analysis Electronic Notebook

Problem Statement: The environmental process is complex. Practitioners lack easy access to guidance information needed to conduct transportation environmental analyses. An abundance of written guidance information is available; however, knowledge of its existence and its accessibility is limited. As a result, professionals have difficulty quickly and efficiently assembling environmental analysis guidelines which are available from many different sources. This is complicated by frequent turnovers and changing guidelines. There is a need to develop and implement a user friendly environmental analysis guidance information system which is readily accessible and dynamic.

Proposed Research: Develop a dynamic transportation environmental analysis information system in the form of an electronic notebook series. Among the components of this electronic information system are: a library of laws, regulations, policies, procedures and guidance documents; a directory of contacts; environmental analysis flow charts; widely acceptable methodologies for environmental analyses; computer models for environmental analyses; environmental database access information; environmental analysis expert system access and case studies. Access to information in the system shall be made available through on-line computer access. The components of the system shall be developed using a phased approach as modules and made available upon completion. Existing information shall be incorporated into the system first. New information shall be incorporated as it becomes available. Recommendations will be made for maintaining the system.

Cost: $175,000
Duration: 18 months

Title: Procedures for Applying ISO 14000 to DOTs and Other Transportation Agencies

Problem Statement: Current environmental management practices, policies and decisions made in transportation agencies do not always consider direct and indirect environmental consequences. Operational and policy decisions sometimes produce negative environmental impacts which are contrary to agencies' mission to plan, design, construct, maintain and operate environmentally-sound transportation systems. There is a need to implement modern management techniques that improve institutional environmental awareness and operational efficiency.

Proposed Research: To examine International Standards Organization (ISO) 14000 - Environmental Management Systems, for departments of transportation agencies that would increase environmental awareness; incorporate environmental considerations into decision-making; and establish structure and responsibilities, monitoring and measurement procedures, and implementation criteria. The management principles should be incorporated into all aspects of the policies and procedures of the transportation agency.

The proposed research should: (1) Identify ISO 14000 environmental management practices to be used in DOTs and transportation systems. (2) Develop procedures for applying ISO 14000 to DOTs and other transportation agencies. (3) Prepare a pilot study for ISO 14000 implementation and a report on the results. (4) Establish recommended standards, practices and principles for implementation of ISO 14000 by DOTs and other transportation agencies.

Cost: $500,000
Duration: 48 months

HAZARDOUS MATERIALS TRANSPORTATION

WORK GROUP PARTICIPANTS

Michael Bronzini, *Facilitator* Chris Barkan Rae Zimmerman

BACKGROUND PAPER

No background paper was prepared for this topic.

RESEARCH NEEDS STATEMENTS

Title: Data for Hazardous Materials Transportation Decision-Making

Problem Statement: The inconsistencies in and incompleteness of current hazardous materials transportation databases cause difficulty in conducting objective comparative risk and safety analyses, formulating appropriate and effective policies and programs, and supporting other decision-making needs. Such analyses require accurate and complete data on: (a) the quantity of hazardous materials that move along specific transportation modes and routes and through specific terminals; (b) the number of accidents and incidents that occur along these modes and routes; (c) if there is an accident, the chances that a release of material will occur and the severity of the release incident; and (d) population and other categories of exposure. There is a need to evaluate existing data collection processes and databases to see how well they meet these requirements, identify their strengths, weaknesses, inconsistencies, and data gaps, and propose approaches for improving the coverage and quality of data.

Proposed Research: Identify the data requirements for hazardous materials transportation decision-making, including commodity flows, vehicle movements, accidents, incidents, material releases, incident severity, containment configurations, population exposure, employment exposure, motorist and operator exposure, special populations, sensitive environments, subjective factors for risk assessment, and other critical data elements. Assess the relative priority of need for these data. Examine the data that is already being collected by government and industry, and the respective data collection processes. Characterize the data according to cost of collection, variability, reliability, proprietary nature, legal liability, and other important factors. Develop methods that would be widely applicable across modes, industry segments, and all levels of government to make existing data collection processes consistent and reliable. For example, look into systems for uniquely identifying incidents and their geospatial and network locations, so that relevant data will neither be double-counted nor lost. Investigate the use of surrogate data (e.g.., automobile accident experience as a predictor of relative truck accident probabilities) and other innovative approaches to using ancillary data sets to meet some of these needs. Identify data needs that cannot be met with the existing processes, and recommend revised or new data collection programs and data management systems. Establish the priorities of all of these needs, estimate the costs of various levels of meeting these needs, and assess the feasibility of the alternative or recommended programs. The focus of this project should be on improving the consistency, reliability, and usability of existing data collection processes, and cost-effectively meeting any outstanding needs of high priority.

Cost: $350,000
Duration: 18 months

Title: Environmental Hazards of Materials in Transportation

Problem Statement: The lack of a consistent, scientifically based approach to evaluate the environmental hazards of chemicals and other materials in transportation limits the ability for industry and government to rationally allocate resources to efficiently prevent environmentally harmful spills. There has been extensive work on the effect of specific individual chemicals on individual organisms and ecological communities. However, there is no general approach that enables objective comparison of the relative hazard posed by the wide variety of materials commonly transported and how they interact with the environment in the event of a release. The current DOT system for classifying hazardous materials does not appropriately consider environmental hazard in a systematic or comprehensive manner. The lack of a method to accomplish this prevents objective assessment of the relative environmental risk posed by transportation activities, thereby limiting industry and government's ability to prioritize measures for spill prevention.

Proposed Research: *Phase 1 -- Review and Plan Development* - Review extant environmental dispersion and environmental toxicity models to develop a baseline understanding of the state-of-the-art for environmental hazard assessment. This review should consider the effect of spills on soil, groundwater and surface water bodies and include evaluation of approaches ranging from the organism to the ecosystem level. The deliverables for Phase 1 of the project should include:

- A concise discussion of the problem and a plan for how to address it. This would include determination of the potential users of this information and review of their needs.
- A review of the environmental hazard assessment methodologies currently available, including an evaluation of their strengths and weaknesses in the context of the larger objectives of this project.
- A summary and description of the types of chemical property and environmental data likely to be needed and an assessment of their availability. The review of the environmental data needs should include consideration of the ability of various GIS environmental databases to support them.
- A work plan for development of a practical, scientifically based approach to evaluating environmental hazards of chemicals. The plan would take into account the constraints posed by data availability and include an approach for development of regulatory criteria for classifying chemicals into a system of environmental hazard class.
- A plan for development of testing requirements to enable DOT environmental hazard classification.
- A review of the potentially relevant laws and regulations pertinent to environmental impacts from chemical spills in order to understand how statutory changes might be implemented.

Phase 2 - Implementation - Execute the plan developed in Phase 1. This would involve development of the technical information, methodology, and testing requirements needed to objectively evaluate the environmental impact of materials spilled under the variety of environmental conditions encountered in transportation. The products of this work would be integrated models and data to characterize environmental risk thereby enabling better informed modifications to packaging and operations to most efficiently mitigate the risk.

Cost: $800,000
Duration: 39 Months

Title: Barriers to the Use of Risk Assessment as a Decision-Making Tool for Hazardous Materials Transportation Risk Management

Problem Statement: Risk assessment is a powerful tool for management of hazardous materials transportation risk. It has the potential to substantially improve the rational basis for decisions on allocation of safety resources and regulatory activity. Despite these potential benefits, state-of-the-art risk assessment methods are not being extensively used in hazardous materials transportation decision-making and there is some reluctance on the part of both industry and government to employ this method. At least three factors contribute to this reluctance:

- Information: The data and information requirements to conduct risk analyses can be substantial and their lack of availability or the cost to develop them can be an obstacle.
- Complexity: The complexity of risk analyses has two effects that can stymie its use for hazardous materials transportation safety decision-making:

  1) It may be difficult to find qualified individuals within a company or agency to develop appropriate questions and conduct analyses.
  2) It can be difficult to effectively communicate the value of the process and the meaning of the results

both inside and outside the organization investigating a question.

- Liability Concerns: The increasingly litigious nature of society can inhibit the investigation of safety issues because of concern that liability is increased in the event of an accident if the potentially culpable party had knowledge about the likelihood of the event.

In order to overcome these barriers and improve the efficient allocation of resources for hazardous materials transportation safety, the effect of these barriers needs to be understood.

Proposed Research: Investigate the issues identified above through surveys and interviews of relevant institutions and organizations. These should include hazardous materials carriers, shippers, transportation vehicle manufacturers and owners, and relevant state and federal regulators. Work with organizations in each of these categories and identify several opportunities to apply risk-assessment methods to a significant safety question. Evaluate the effect of each of the three factors (and other factors that might be identified) in terms of its effect on whether risk-assessment was used. Organizations that had both successful and unsuccessful experiences using risk-assessment methods should be sought so that the factors affecting success could be contrasted.

- Information: Determine the information requirements needed for each question of interest and the effect of the availability or cost of this information on the decision to use risk-assessment.

- Complexity: Determine the availability of individuals trained in the use and interpretation of risk assessment within each organization. Staff availability to develop questions or conduct analyses should be summarized and contrasted between and among types of institutions. In those cases in which use of risk-assessment had been considered or carried out, evaluate the effectiveness of communicating the idea or the findings and implementing the results internally and externally.

- Liability: Investigate the effect of liability concerns on decisions to employ risk-assessment by determining the extent to which each organization believed it was constrained from investigating questions due to fear of litigation. A critical element for each opportunity considered for each organization would be to determine the economic value of the risk that would be identified and potentially reduced, compared to the estimated increase in liability that the organization perceived as a result of the identification of the risk. Included in this would be a study of past cases in which knowledge may have affected settlement costs.

Cost: $250,000
Duration: 18 Months

Title: Hazardous Materials Routing Rationale and Criteria

Problem Statement: Routing of hazardous materials has become a sensitive issue with the public due to concerns over the potential risk and community impacts in the event of a release of material. At the same time, routing regulation imposes costs on carriers, shippers, and public agencies, all of which are ultimately borne by the public. There is a need to assess the value of hazmat routing regulation as an approach to managing transportation safety, and to examine the criteria that should be used in establishing approved routes. A related need is to provide user-friendly guidelines and tools to facilitate the proper application of the recommended route designation methods.

Proposed Research: *Phase 1 - Rationale of Hazardous Materials Route Designation* - Identify the objectives that are to be achieved through hazmat route regulation, or through the siting of hazardous materials terminals and handling facilities. Assess the levels of risk reduction that can be achieved through this approach, and compare this to risk reduction via other means. Estimate the cost-effectiveness of the alternative approaches, including examination of the incidence of costs and risk, and develop recommendations on when routing regulation should be among the preferred alternatives for risk reduction.

Phase 2 - Criteria for Route Designation - Identify the factors that should be considered in selecting hazmat routes, and how the factors should be weighted or otherwise combined in the route designation process. Identify the parties who will be involved in routing and assess their risk assessment decision support needs. Identify the data and methods that are available to implement the recommended route designation procedures, and develop user-friendly mechanisms to place these tools into the hands of the route designation analysts and decision makers. Depending upon the criteria included in the routing methods, the decision support tools might address factors such as the influence of emergency response capabilities on risk, incorporation of sources of variability or uncertainty, impacts of time of day and traffic levels, use of local or situation specific data in lieu of default factors, and ability to distinguish between routine operations and emergency situations.

The research should cover highway transportation, other modes, and intermodal transport where the public will become involved in the route selection or siting process.

Cost: $550,000
Duration: 30 Months

Title: Integration of Design, Operation and Maintenance of Hazardous Materials Transportation Facilities and Equipment

Problem Statement: Hazardous materials transportation releases can occur because the design, operation and maintenance functions are not well integrated. This can apply to facilities (including roadway networks) or equipment. For example, a piece of equipment might have been designed whose operation was unclear, complex, or unworkable to the operators, leading to a failure of the equipment and resulting in a release. Operators may not be able to compensate for these types of problems because of the lack of information, knowledge or understanding of the interactions between the system components. They may not understand the system functionality, what kind of compensation or intervention can be made at a particular point, or have a lack of motivation to accept and act upon the information about the system (a "not my problem" mentality).

Proposed Research: 1. Examine hazardous materials release scenarios to: (a) understand linkages among design, operation, and maintenance features; (b) determine the extent to which lack of system integration contributes to the releases and their severity; and (c) use fault tree analysis to portray the linkages and their implications.

2. Using the output from the examination of scenarios, investigate how design, operation and maintenance features of facilities and equipment can be linked and integrated with human factors to minimize the incidence of hazardous materials spills.

3. Determine how critical aspects of these linkages can be most effectively communicated and implemented by management and operators.

4. Develop education, training and communication strategies that encompass information quality, availability, comprehension, and motivation. Apply these along the entire continuum of design, operation and maintenance (including feedbacks to redesign, etc.).

5. Identify and evaluate the changes in the management process needed to successfully integrate the design, operation and maintenance functions. Identify the barriers to the needed changes and the means to overcome them.

Cost: $250,000
Duration: 18 Months

Title: Effectiveness of Highway Operational Measures to Reduce Risk in Hazardous Materials Transportation

Problem Statement: Various types of highway operational measures have been proposed for reducing risk in hazmat transport, but there is little experience in designing these types of measures and scant evidence of their effectiveness. For example, the effectiveness of designated lanes for hazmat carrying trucks needs to be investigated. If designated lanes are implemented, what types of restrictions should be used and what impact will this have on the probability of truck accidents? What roadway geometrics would promote safer hazmat highway operations? Similarly, safe havens are sometimes required for storage of unattended hazmat vehicles, but there are no generally accepted criteria for what constitutes an acceptable safe haven. Likewise, time of day restrictions on hazmat operations have been suggested, but with no consistency of application or detailed analysis of expected consequences. Some agencies have proposed restricting hazmat shipments in urban locales to nighttime hours, when congestion and exposure may be lower, while others have proposed restricting shipments to daytime hours when emergency response capabilities may be greater. Such contradictory approaches need to be resolved.

Proposed Research: Identify highway operational measures that have been proposed or have the potential to reduce hazmat transport risk. Compile data on those measures that have been tried, focusing on the rationale or design criteria used and the operational results achieved in practice. Estimate the range and incidence of the costs involved in implementation of highway operational measures. Identify data and methodologies that can be used to assess the cost-effectiveness of such measures, and conduct assessments of the most used or most promising measures. Prepare design guidelines for highway operational measures for reducing hazmat risk.

Cost: $300,000
Duration: 15 months

Title: Socioeconomic Impacts of Hazardous Materials Transport

Problem Statement: The nature and existence of spatial patterns in hazardous materials traffic with respect to sub-populations or population sectors have not been analyzed. Understanding such patterns is critical to determining if inequities exist in exposure to risk, such as those pertaining to environmental justice concerns.

Proposed Research: Evaluate if hazardous material transportation patterns and risk are more spatially concentrated in, or proximate to, socially or economically disadvantaged sub-populations. Research is needed with respect to:

1. How such sub-populations are defined and identified

2. What methods and criteria can be used to determine whether or not inequities exist, including measures of risk perception

3. The application of methodologies to determine the existence of spatial patterns and the existence of inequities

4. How one would remedy such inequities in terms of rerouting, increased safety design, operation and maintenance, etc., and

5. How to communicate the outcome of the research to decision-makers in the transport sector and to the general public.

Cost: $250,000
Duration: 18 Months

HAZARDOUS WASTE

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BACKGROUND PAPER

Hazardous waste issues are continually coming to the social, economic and political forefront in the United States. A few illustrations of this fact are the intense debate on Superfund and Clean Water Act reauthorization, the hundreds of billions of dollars invested annually in hazardous waste management, cleanup, and research, and the keen interest in the evolution of a uniform environmental responsibility and management standard being developed by the International Standards Organization (ISO). The development, operation and maintenance of the transportation infrastructure in this country will be increasingly impacted by hazardous waste issues as regulatory requirements continue to increase and the ability to locate projects in areas which are free of pre-existing contamination continues to decrease to the point that reuse/redevelopment of contaminated properties is unavoidable.

Currently, almost every aspect of transportation is in some way impacted by the myriad of hazardous waste-related laws and associated regulations including: the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund); the Toxic Substances Control Act (TSCA); the Clean Air Act; the Clean Water Act; the Safe Drinking Water Act; the Pollution Prevention Act; the Marine Protection, Research and Sanctuaries Act; the Occupational Safety and Health Act (OSHA); the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA); the Hazardous Materials Transportation Act; and, the Atomic Energy Act (and related federal nuclear waste statutes). Furthermore, there are state equivalents to many of these regulations that may even be more restrictive than their federal counterparts. As a result, there are often extreme costs associated with complying with the extensive regulatory requirements, and environmental managers everywhere are constantly seeking more efficient, inexpensive, and/or innovative solutions to address their waste-related issues. Specific areas where cost savings and/or operational improvements are currently being sought by government agencies and the private sector include pollution prevention and waste minimization, innovative waste treatment and handling technologies, reuse of contaminated materials and properties (Brownfields), and risk management.

Most of the hard research on hazardous waste issues, to date, has been performed outside of the transportation arena by such agencies as U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), the U.S. Air Force, and others, as well as private industries and industrial associations. However, further research is necessary and prudent to help transportation agencies to more efficiently and effectively deal with the numerous regulatory requirements and the very significant resource demands associated with hazardous waste and materials management. Such research can have the immediate benefit of synthesizing and sharing the different expertise and lessons learned from the hundreds of transportation agencies as well as other organizations that are confronted with these same issues. A more formal, perhaps on-line, data repository would enhance the sharing of information, particularly so that the transportation industry can take better advantage of the hazardous waste research being performed by the non-transportation sections. Additionally, research and information exchange could assist in the development and implementation of specific improvements in the way hazardous materials issues are currently being evaluated and addressed.

The most cost-effective way to minimize adverse impacts and future liabilities associated with the generation of wastes is often through the use of pollution prevention and recycling programs, staff and community education programs, a more programmatic cradle-to-grave approach, and/or emerging waste treatment technologies. With passage of the Pollution Prevention Act of 1990 Congress declared that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner. This established the national policy and hierarchy of effective waste management. In support of this concept, much of the recent research and experience regarding hazardous waste shows that waste prevention is preferable to after-the-fact waste management and cleanup. Although most transportation construction projects require involvement with after-the-fact wast management issues, operation and maintenance (O&M) aspects of transportation have greater opportunity to deal with potential waste prevention issues.

By assessing applicable regulatory constraints and evaluating all phases of a client's activities at a site for opportunities to reduce, recycle or eliminate potentially harmful byproducts which must later be treated and/or disposed of, waste problems can be treated before they even occur. The avoidance of waste generation and discharge not only saves the direct costs of disposal and remediation, but also achieves substantial savings in costs associated with permitting, reporting, compliance and liability. Where complete elimination of waste is not possible or environmental contamination already exists, new and innovative technologies may offer the most cost-effective solution although their adoption often requires additional analysis and negotiations with both clients and regulators. In still other cases, the most innovative technology is to let nature treat one's waste problems (for example, through natural attenuation or intrinsic bioremediation) or to simply adopt onc's waste problem into the future use of the property, such as by establishing deed restrictions that allow only those land uses that are compatible with current or safe reuse.

In recent years, regulators, government officials, and researchers have begun to realize the value of Brownfields due to their often advantageous location in developed areas where vacant real estate may be a premium or where affordable land eligible for urban revitalization is available. The challenge is to clean up the site in a manner which is protective of health, yet is cost-effective and efficient while limiting the future liability associated with the contamination that remains at the site. The reclamation of contaminated properties has become easier in the past few years due to several trends. Recent initiatives by the U.S. Environmental Protection Agency and state regulators, as well as federal legislators, have focused on limiting the potential liability that might arise from these properties. Incentives have been proposed to encourage the reuse of these properties, and many state environmental agencies have produced guidance and regulations to allow cleanup efforts to be guided by the future use of the property rather than conservative and often unrealistic, pristine scenarios.

To adequately protect the public and the environment, risks associated with addressing and transporting hazardous wastes and materials must be appropriately evaluated and managed. The conventional approach to risk management (which is still applied in many places) was to evaluate hazardous materials and pollution situations under worst-case scenarios regardless of how realistic such a scenario was. This generally resulted in the required identification, evaluation and implementation of very costly (and often ineffective) solutions and technologies. In contrast, the modern trend in risk management is to evaluate and control sources of potential exposure and risk, and to integrate into the evaluations such considerations as societal concerns, economics, politics, and planned land uses. This approach is becoming more and more accepted as the best means of developing appropriate waste management alternatives and of properly allocating the generally scarce resources available for implementing these alternatives. Comprehensive risk management programs are being developed which force managers to consider and evaluate risk-related issues and data needs from the planning stage of a project through final decision-making and implementation. These programs also consider and attempt to address the frequent tension between giving priority in funding to the problems with highest associated risks to human health or the environment (worst-first approach) as opposed to the problems where the most significant improvement can be achieved with the finite available resources (cost-benefit approach). The key to this analysis is being able to develop risk assessment and cost modeling methods which fairly and consistently quantify the relative risks, benefits and costs of each programmatic decision.

Together with a review of the biggest and most urgent information needs of transportation managers, the timeliness and importance of the issues highlighted above

played an important role in the development, screening and refinement of the research needs statements provided herein.

Based on an assessment of factors such as urgency of need, time required for completion, and magnitude and likelihood of required funding, it is proposed that first priority be given to performing the research described in needs statements two, three and four.

RESEARCH NEEDS STATEMENTS

Title: Evaluating Constituent Leachability, Migration and Fate Issues Associated with Incorporation of Contaminated or Reusable Materials in Highway Construction

Problem Statement: The incorporation of contaminated (hazardous or non-hazardous) materials or other re-usable materials in highway construction is a potentially beneficial and cost-effective method of re-use and recycling that reduces the use of virgin materials. Policies and legal mandates requiring recycling of materials/wastes are now in place in many jurisdictions and are anticipated to increase in the coming years; many even specify that certain percentages of recycled or waste materials be reused. However, use of materials that are considered to be "contaminated" or "waste" (thus, potentially "hazardous") raises questions about the potential for adverse impacts due to the possible release of toxic and/or hazardous constituents into the air, groundwater and/or surface water. The results of this research are intended to benefit transportation agencies by providing supporting data on typically encountered materials which will either confirm or refute the advisability and safety of incorporating such materials in highway construction.

Proposed Research: Evaluate the environmental impacts of re-used and recycled materials by designing and building test roadway stretches that incorporate these materials and measuring the fate and transport of the potentially hazardous constituents present in the reused/recycled materials. Steps in the research project shall include:

1. Developing a list of the most prevalent and/or problematic candidate materials by researching existing data and reports and by executing a survey of transportation agencies to fill any data gaps;
2. Identifying those materials to be evaluated in further detail based upon potential for migration and adverse effects, frequency of occurrence in highway practice, availability of existing data, and need for material-specific research;
3. For the materials which are selected, evaluating where in the roadway/right-of-way the materials could or should be incorporated (slopes, roadbase, asphalt, etc.);
4. Developing and implementing a testing program (bench and/or field scale as appropriate) to provide data on leachability, aging, fate, mobility, etc.; and
5. Evaluating and reporting on a.) the projected extent of impacts to the environment (e.g., leachate, air-borne transport, effects on receiving streams, toxicity, ability to establish vegetative cover, etc.), and b.) available mitigation or application techniques to minimize the potential for adverse impacts.

Cost: $500,000
Duration: 3 years

Title: Develop a Needs Assessment Protocol for Transportation-Related Environmental Management Information Systems (MIS)

Problem Statement: Masses of data, both internal and external, are often underutilized within transportation organizations. The development of Management Information Systems for environmental applications in transportation is a means to manage and effectively utilize such data. Types of environmental information useful to organizations may include: wetland delineations, hydraulic information, structure and utility location, contaminated materials location, etc. Ready access to and integration of various data could greatly assist transportation organizations in minimizing costs associated with activities such as alternatives analysis, right-of-way acquisition, maintenance operations, etc. In order to reduce duplication of effort among transportation organizations in developing such systems, a needs assessment protocol should be developed.

Proposed Research: The recommended research focuses on identifying and characterizing the information management needs of a broad range of transportation-related organizations. The protocol to be developed should be a comprehensive "How to Guide" which sets forth both the process and recommended tools to produce a sound and complete MIS needs assessment. The protocol should, at a minimum, include a description of

how the subject organization should perform the tasks associated with scoping the environmental component of a comprehensive MIS. Specific tools (e.g., interview guides, sample questionnaires, reference lists, report outlines) that are applicable and appropriate should also be developed and presented. The protocol should describe how to:

1. Characterize existing types of information to be considered for management. A review of current databases, products and information sources is envisioned.
2. Identify new databases, products and information sources or services that will be required based on current and anticipated responsibilities and priorities.
3. Characterize the user base. Identify representative potential users and characterize the current methods for accepting and utilizing information services. Existing internal and external information resources, technical and communications capabilities and level of sophistication should be examined. Surveys, questionnaires and interviews may be appropriate.
4. Assess user requirements. Define those areas in which end-users express the greatest interest and need. Surveys, questionnaires and interviews may be appropriate.
5. Develop a user needs definition report detailing the interests and system requirements from the user perspectives. The report should set forth short term (1-2 years) and long term (5-10 years) needs and specific user priorities of an information management system.
6. Assess appropriate information technologies including software application delivery tools and effective communication tools. This step in the protocol should also consider existing and planned operating environments, communications infrastructure and storage technologies.
7. Prepare an Information Technology Assessment report describing the technical feasibility and costs to design, build, operate and maintain various information management system alternatives.
8. Identify potential system co-funders, opportunities to generate revenues once the system is operating, and the cost-efficiencies to be realized via the rapid access to multiple databases, information sources and analytical tools.

The detailed protocol developed through this research will allow responsible individuals (without extensive systems information experience) to adequately define the scope, cost and timing of developing or upgrading the environmental component of an MIS. The outputs of the protocol should address:

1. The specific information management objectives of the user organization.
2. Compatibility and system architecture concerns as related to the user organization's existing MIS.
3. The specific resources (labor and money) and schedule associated with the proposed system development or upgrade.
4. The data and information linkage requirements with users that are both internal and external to the organization.
5. The potential increases in the efficiencies and productivity resulting from various system configurations.

The output will be readily employed in the development and preparation of an implementation plan which specifies the hardware, software and expertise necessary to cost effectively procure, install, document, and maintain the selected information management system configuration.

Cost: $75,000 - $100,000
Duration: 6 - 9 Months

Title: Minimizing Transportation Agencies' Liability Associated With Use of Contaminated Property

Problem Statement: Historically, transportation agencies have avoided using contaminated properties for project construction. Major concerns have been: increased costs and delays due to regulatory compliance requirements; and, more significantly, uncertainty about future liability.

Recently, the federal and state governments have initiated legal and/or administrative changes to encourage cleanup of contaminated property. As the private and public sectors remediate abandoned, polluted properties and restore them to the economic mainstream, transportation agencies will be expected to play a cooperative role in providing access to these revitalized areas.

The use of contaminated sites offers transportation agencies the opportunity to acquire property at reduced costs. Technological advances and lesser remediation requirements reduce cleanup costs. However, despite changes in the regulatory climate and potential decreases in cost of cleanup, transportation agencies remain wary about the uncertainties of liability -- both for future cleanup and for third-party suits.

Therefore, the public transportation community would greatly benefit from a research project that identifies

ways to minimize liability when using contaminated property.

Proposed Research: The proposed research should include the following tasks:

1. Identify the level of legal protection available to public transportation agencies in:
   - state cleanup laws
   - federal cleanup laws and administrative guidance;
2. Assess availability of defenses to third-party liability;
3. Survey transportation agencies to identify case studies; existing and anticipated law suits; and issues involving use of contaminated property;
4. Identify approaches to minimize liability, such as:
   - engineering controls
   - appropriate use of land use restrictions and other institutional controls
   - risk based approaches to make decisions regarding contaminated property use;
5. Prepare a summary of findings report.

Cost: $140,000
Duration: 6 months

Title: Interactive Right-to-Know, Health and Safety and Waste Management Awareness Training for Transportation Agency Employees

Problem Statement: Transportation employees throughout the country encounter hazardous materials or hazardous waste on a routine basis, some on a daily basis. Many of these individuals have received little or no training relating to health and safety issues. Unfortunately, there have even been several casualties which could be attributed to the lack of proper training. There is no training program currently available which is specifically designed for transportation employees in these important issues.

There are several commercial health and safety training programs currently on the market. However, these programs were developed to train employees of industrial facilities such as chemical manufacturers or other industries which store large quantities of hazardous materials and generate large amounts of hazardous waste. Providing these commercially available programs to transportation employees can cause confusion since the situations transportation employees may encounter are not typically of the same magnitude. Untrained employees can mishandle environmentally sensitive materials, resulting in expensive cleanups or endangerment of personal safety and health.

In addition, regulations are periodically revised and updated, making it difficult to keep training programs current. Transportation agencies do not have the personnel to continually update training programs.

A CD ROM type interactive training program needs to be developed, geared specifically for transportation employees, and covering health and safety, right-to-know, and waste management awareness issues. This training program should be developed with three independent elements (health and safety, right-to-know, and waste management awareness). It should be formatted so that it can be used by an individual or in a classroom setting. The software cannot be proprietary and must be developed so that it can be easily updated on an annual (or more frequent) basis, as the regulations are updated.

The use of this system will result in the following benefits: reduced costs, increased efficiency, minimization of employees utilized for training, and employees' increased awareness of the subject matter.

Proposed Research: Review currently available interactive CD ROM's to determine best format. Several different transportation agencies should be visited to observe common practices and similar materials routinely used. Transportation personnel and equipment must be utilized in program development. Research for training elements would include determining various situations a transportation employee may encounter (such as a release of a hazardous material on a roadway, routine activities at a maintenance facility, construction or geotechnical drilling projects that encounter contaminated material, etc.), general types of hazardous materials typically used, labeling requirements, shipping documents, transportation of hazardous materials and waste requirements, release reporting requirements, and a list of waste generation processes.

The end result would be an interactive CD ROM that could be distributed nationwide to cost-effectively train large numbers of transportation employees in the areas of health and safety, right-to-know, and waste management awareness.

Cost: $150,000
Duration: 12 Months

Title: Evaluate the Use of Universal Wastes and Other Transportation-Generated Wastes as a Replacement for Virgin Materials in Highway Construction

Problem Statement: The use of universal wastes and other transportation-generated wastes combined with or in

place of virgin materials has the potential to reduce costs of waste disposal (of transportation wastes) and requirements of virgin materials, and end costs for material associated with transportation construction and operations. Replacing or combining virgin materials with wastes identified as universal wastes or other transportation-related process wastes currently requires a case-by-case evaluation of the availability, benefits, cost, and functional equivalency to virgin materials; identification of potentially-regulated constituents; and determination of ultimate environmental stability. The cost advantages of the use of alternative materials can be easily lost if each state highway agency has to conduct independent evaluations of each of the potential options. This can represent a significant commitment of limited resources that may have a benefit only for an individual project. To have a pre-developed evaluation and rigorous comparison of material use options using standard materials testing protocol would be cost-effective and beneficial and help meet the regulatory mandate to recycle.

Proposed Research: Develop a comparison matrix of selected materials versus virgin materials by replacing some or all of the virgin raw materials with a universal waste or other transportation generated wastes. The baseline for any substitution comparison shall be on an "equal- or better-quality" finished product. Comparisons shall, at a minimum be consistent with regulatory requirements and consider variables such as cost, availability, quality of the end product, constructability, and environmental stability of the final product. The comparison matrix shall include:

1. Evaluation of candidate replacement materials/wastes (i.e., paint wastes, street sweepings, foundry slags, bottom ash, etc.);
2. Determination of the availability, volumes, and general source locations of such materials;
3. Identification of candidate uses (i.e., fill, aggregates for Portland Cement Concrete or Asphalt Cement Concrete, flowable fill, etc.);
4. An economic analysis of the benefits of re-use;
5. Commercial usefulness;
6. Functional material evaluation or characterization;
7. Liability issues of use of potentially contaminated materials;
8. Environmental assessment of replacement materials before and after incorporation into a final product; and
9. Management system assessment (need for tracking of materials, environmental impacts, cost, locations of placement, etc.).

Cost: $250,000
Duration: 18 Months

NOISE

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BACKGROUND PAPER

Nearly every person in the United States is somehow affected by noise originating from transportation sources. The primary impact area is for urban residents affected by noise from major transportation systems. However, suburban and rural residents are also affected by noise from interstate and rural highways, aircraft and train sources.

Transportation noise affects people in a variety of ways and people perceive noise subjectively. An individual located hundreds of feet from a highway may experience a very low level of transportation noise; however, this noise may be perceived as more annoying than other, natural noises that may be louder, such as birds and insects. Reflected noise from noise barriers, rock cliffs and other structures may also be perceived as annoying even though the measured levels of sound are quite low. Transportation noise may affect the ability of people to carry on conversations, to concentrate in work and school settings, and to sleep.

Noise is a major issue associated with the design and construction of new transportation systems, as well as improvements to existing transportation systems. Current technologies make it impossible to design a transportation system that does not produce noise. In addition, in an era of reduced government funding, the cost of constructing mitigation measures for environmental impacts is being strictly scrutinized. This includes noise mitigation measures, which can be very expensive. Noise barriers can cost in excess of $2 million per mile. In light of these considerations, issues in the forefront of transportation noise research over the next few years include: improvements in methodologies used to predict noise levels from transportation sources; gaining a better understanding of factors affecting human annoyance with noise; and analyzing noise mitigation measures with emphasis on more aesthetically pleasing methods and alternatives to traditional noise barriers.

The Federal Highway Administration's (FHWA) Highway Traffic Noise Prediction Model and, subsequently, its related STAMINA 2.0/OPTIMA software programs for highway traffic noise prediction and noise barrier design have been used by analysts for almost two decades. During this time, improvements have occurred in state-of-the-art methodology and technology for noise prediction and barrier design. In addition, the ability to predict transit noise has been imprecise in the past, with no standard methodology or set of impact criteria available for predicting transit noise.

Many of the traditional problems with the prediction of noise from transportation sources have been recently solved, or at least, significant progress has been made in rectifying these problems. Recently, there have been many exciting developments in the field of transportation noise prediction and control by the key federal transportation agencies. New noise prediction models have been developed by the FHWA, the Federal Aviation Administration (FAA) and the Federal Transit Administration (FTA). The introduction of these new models has enhanced the ability to accurately predict noise originating from specific transportation sources.

The FHWA Traffic Noise Model (FHWA TNM) is an entirely new highway traffic noise prediction model that has a Microsoft Windows interface and an internal Computer-Aided Design Drawing capability. The FHWA TNM will calculate traffic noise levels using totally new acoustical algorithms as well as newly-measured emissions levels for five standard vehicle types, i.e., automobiles, medium trucks, heavy trucks, buses and motorcy-

cles. The calculations will be performed in one-third octave bands for each of two subsource heights per vehicle. The FHWA TNM will output overall A-weighted sound levels for locations with and without noise barriers. It will allow for analyses of (1) both constant-flow and interrupted-flow traffic, (2) attenuation due to rows of buildings and dense vegetation, (3) effects of parallel noise barriers, (4) results of multiple diffractions, and (5) noise contours. The introduction of this new model promises to improve the accuracy as well as the ease of highway noise prediction.

Atmospheric effects on propagation have not been adequately researched to be incorporated into the highway traffic noise prediction process. Research should continue to determine the contribution of these atmospheric effects, with the goal of appropriately including this factor within TNM.

It has long been recognized that there is a relationship between roadway pavement type and noise generation characteristics. Research should be continued to analyze tire and pavement noise characteristics. Studies should specifically include evaluation of the effects of age and wear and the long-term stability of various pavement types.

Construction of noise barriers has been the most often used measure to abate highway traffic noise. Noise barriers have received mixed reviews from residents behind the barriers, as well as from drivers traveling on the highways. Many people find noise barriers aesthetically unpleasing and find that they lead to a monotonous driving experience. Research should continue to develop improved designs for noise barriers that are more effective, economical and aesthetically pleasing, including the possibility of using alternative building materials, such as recycled materials.

The FAA Integrated Noise Model (INM) has been updated to run under Microsoft Windows 95. INM Version 5.1 also includes a U.S. Air Force military aircraft noise database. This model update makes INM more user friendly. Research is ongoing by FAA and the airline industry to reduce the noise generated by aircraft and to design flight paths that will be efficient and minimize, to the greatest extent possible, airport noise impacts. The major methods for mitigation of airport noise impacts are purchase of affected properties and sound insulation of affected structures. Since the purchase of impacted residences may not be economically feasible, research should continue on improving the use of sound insulation to mitigate airport noise impacts. A comprehensive study evaluating various sound insulation treatments in use in the U.S. and in other countries should be performed, evaluating cost and effectiveness. A guidance document should be developed to assist airports in setting-up and managing sound insulation programs.

The FTA has developed a methodology for transit noise prediction and guidelines for impact determination, found in *Transit Noise and Vibration Impact Assessment* (dated April 1995). This document fills a gap that previously existed in the area of assessment of transit noise. Continued research is needed in this area, specifically the development of a procedure for estimating sound barrier performance for railroad noise.

Many areas are affected by noise originating from more than one transportation source. This is true in many urban areas, where residents may be affected by a combination of highway, rail and aircraft noise sources. Research is necessary to develop a methodology for the integration of noise originating from multiple transportation sources.

RESEARCH NEEDS STATEMENTS

Problem Area: AIRCRAFT NOISE

Title: Supplementary Metrics for the Evaluation of Aircraft Noise Impact

Problem Statement: The Day-Night Average Sound Level (DNL) is the acoustic metric currently used by the Federal Aviation Administration in evaluating the community impact of aircraft noise around airports and in establishing a design criterion for residential sound insulation programs. Recent experience has indicated that the use of this metric alone may not be technically sufficient in many situations. In addition, much of the public's perception is that an averaging metric, such as DNL, does not correlate well with their response to the intruding aircraft noise.

Four areas in which responses to aircraft noise appear to be greater than expected from the existing aircraft DNL are: (a) near small and mid-sized airports where the average Sound Exposure Level (SEL) of single aircraft overflights, at a given DNL contour, is much greater than the corresponding SEL at that DNL contour near a large airport; (b) at locations where background noise levels, as characterized by L_{90}, are more than 10 dB below the noise

levels produced by aircraft overflights, as characterized by L_{10}; (c) at locations distant from airports where new air traffic patterns have introduced recognizable aircraft noise into regions that previously did not often experience such noise events; and (d) near airports at which there has been a discontinuous increase in the amount of air traffic or a dramatic change in air traffic patterns.

Research is required to identify acoustic metrics that can be used to supplement DNL in evaluating community impact and in establishing design criteria for residential sound insulation programs in these situations.

Proposed Research: Research on appropriate supplementary noise metrics should be carried out in three areas: (1) investigation of the use of single-event acoustic metrics to supplement DNL in sound insulation programs, (2) investigation of other cumulative acoustic metrics that account for community response to new or dramatically changed noise exposure, and (3) investigation of noise metrics that compare intrusive noise levels to background noise levels. As part of this research, previous single-event and cumulative noise metrics should be reviewed in terms of the parameters each considers (i.e. total acoustic energy, maximum sound level, duration, number of events, signal-to-noise ratio, variability of sound level, etc.). Where data are available, community reactions to aircrafr noise should be compared in terms of those metrics that appear feasible, including the changes in those metrics as the result of changes in air traffic patterns. Gaps in the existing knowledge should be identified and appropriate acoustic measurement/social survey studies recommended to remove these gaps.

Cost: $200,000
Duration: 12 months

Title: Technology for Aircraft Noise Control

Problem Statement: The state of the art in noise control technology for aircraft is not sufficient to eliminate adverse environmental impacts from airport and aircraft operations. Continued research and development of advanced technology to reduce noise exposure below the current FAR 36 Stage 3 levels is required. Future growth of air transport will be restricted if advanced technology for noise control is not developed. This problem is further compounded by the fact that, while there is a successful but modest technology-specific research program being jointly carried out by NASA and FAA, there is no basic aircraft noise research program at NASA or in any other federal agency.

Proposed Research: The *1991 Environmental Research Needs Statements* identified the development of a comprehensive, coherent, multiyear cooperative aircraft noise research effort between NASA, FAA and elements of the aerospace industry as a critical requirement. Such a program has been developed and is being carried out through the Noise Reduction Element of the NASA/FAA Advanced Subsonic Transport Program. The program is now at midpoint. The program is on track to achieve interim goals for a 3 dB reduction in jet engine noise and a 25% reduction in nacelle treatment effectiveness. Scale model demonstrations of several aspects have been undertaken or will soon be done. However, achievement of the ultimate goal of a 10 dB reduction in community noise has been threatened by budget uncertainties and funding reductions. The Steering Committee of the Noise Reduction Element has also identified additional research needs, including landing gear noise, a review of airframe noise sources and levels with respect to overall community noise levels, and active noise control technology. The Steering Committee is also in process of identifying additional goals beyond the year 2000 when the program is currently slated to end. A successful aircraft noise control technology research and development program requires a sustained commitment over a long time period from both federal agencies and industry. The Workshop reaffirms its identification of basic and applied research in aircraft noise control technology as a critical area of need.

Cost: $194 million through 2000
Duration: 10 years

Title: Effect of Sudden Changes in Noise from Aircraft Operations on Sleep Disturbance and Annoyance

Problem Statement: Recent field studies of sleep disturbance from aircraft noise in Great Britain and in the United States have generated considerable controversy in those two countries since they determined that sleep disturbance by aircraft noise appears to be far less common than had been previously thought. A possible explanation for the results of these studies is that one eventually habituates to the noise environment and numerous awakenings do not then occur. There has been little work done to study this habituation since sudden discrete changes in aircraft noise exposure do not normally occur. Such studies are necessary, however, if the public is to be convinced of the validity of the recent work.

Additionally, the introduction of aircraft overflights into a community that has previously experienced few such noise events generally causes considerable human annoyance. For example, the introduction by the FAA in 1987 of the Expanded East Coast Plan, which modified the

routing of commercial aircraft into the three metropolitan New York airports, caused considerable adverse community response and litigation, even in areas where the aircraft are at cruise altitudes.

Proposed Research: The objective of this research is to study the accommodation of humans to sudden, discrete changes in the noise exposure from aircraft overflights by artificially introducing such an acoustic environment into a selected population of homes and measuring the sleep disturbance and annoyance responses of the residents as a function of time after the introduction of the discrete change.

Cost: $500,000
Duration: 24 months

Title: Assessment of Sound Insulation Modification Procedures

Problem Statement: Currently a large number of airports in the country are either planning to begin 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 airport officials charged with implementing such programs, there is no formal guidance from those airports further along in their sound insulation programs to assist those airports just starting such programs. In addition, most airports manage these programs in very different ways. There has been no assessment of what management techniques work best in various situations.

Proposed Research: Identify, categorize, and assess active sound insulation programs in the United States and other countries. Identify those elements of such programs that are most successful and those elements that are least successful. Develop a guidance document to assist airports in setting up and successfully managing sound insulation programs.

Cost: $150,00
Duration: 9 months

Title: Standardized Testing Methods for Exterior to Interior Noise Reduction

Problem Statement: Currently accepted FAA methods for testing exterior to interior noise reduction on structures vary from region to region and conflict with accepted practice established by the American Society of Testing and Materials and the International Standards Organization. Results from the different test methods vary widely.

Proposed Research: Conduct a study of the various test methods over a range of structures before and after noise insulation. Evaluate the results based on their correlation to perceived improvement as well as repeatability and consistency. Develop a recommended standard test procedure.

Cost: $150,000
Duration: 9 months

Title: Model Building Code Development

Problem Statement: An increasing number of local governmental authorities are implementing building code sections which regulate the sound insulation of buildings around airports. Without the benefit of a model building code to follow, many of the published codes are technically inaccurate and virtually unenforceable. In addition, many states and communities cannot adopt any code which has not already been adopted by one of the three major code agencies.

Proposed Research: Review existing building codes to determine their applicability to sound insulation modifications. Identify those portions of existing codes which are most pertinent. Assess the requirements and capabilities of the various local building code governing bodies. Review the impact of liability issues. Develop a Model Building Code which allows for the setting and evaluation of standards for exterior to interior sound insulation for use by local authorities when addressing planning and mitigation of aircraft noise. Present the proposed model building code to the three major code authorities for consideration.

Cost: $200,000
Duration: 12 months

Title: Computer Model for the Prediction of Noise from Transportation Systems

Problem Statement: There is currently pressure from government officials and the public to extend the analysis of aircraft noise in Part 150 studies and other environmental studies from the 65 dB Ldn contour to the 60 dB and 55 dB Ldn contour. Current aircraft noise models, such as the Federal Aviation Administration's Integrated Noise Model (INM) and the U.S. Air Force's NOISEMAP

program, calculate only the noise in a community due to aircraft, ignoring any contribution from other transportation noise sources, such as highway or rail traffic. Similarly, the Traffic Noise Model (TNM) being developed by the Federal Highway Administration ignores noise contributions from aircraft and rail traffic. Fortunately, each of these models uses the U.S. Air Force's NMPLOT program for producing the final noise contours, which are the primary output of the models. NMPLOT has the capability of combining several noise contours into a single contour representing the sum of the individual contours. Thus, the potential exists for combining these two models (and rail and ship noise models, if such models are ever developed) into a single transportation noise model.

Proposed Research: The objective of this research is to produce guidelines and specifications that could be used by the developers of noise models for individual transportation modes to insure that their model could be combined, at some point in the future, into a single transportation noise model.

Cost: $100,000
Duration: 6 months

Problem Area: HIGHWAY TRAFFIC NOISE

Title: Atmospheric Effects on Highway Traffic Noise Propagation

Problem Statement: Recent 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 the greatest source of error during prediction and measurement. It is possible for noise levels to change by several decibels at a receptor location due to these atmospheric effects. Existing prediction models for highway traffic noise do not account for atmospheric variations. Also, due to a lack of research, the new prediction model FHWA TNM (currently under development) does not include this feature.

Proposed Research: Research is proposed to better quantify the atmospheric effects on highway traffic noise propagation and incorporate them into the latest prediction model and measurement methodologies. The following tasks are proposed to accomplish the goals of this research:

1) 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, a prediction scheme will be developed.
3) Perform validation of the prediction scheme at two "real world" sites along existing highways, utilizing 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.

Urgency and Payoff Potential: Funding this research would provide valuable information for the new Transportation Noise Model under development, allowing increased prediction 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 noise impact.

Cost: $300,000
Duration: 2 years

Title: Upgrade the Federal Highway Administration's Traffic Noise Model (TNM)

Problem Statement: The TNM is a totally new 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. After the TNM is released and users have gained training and experience in its use (a minimum period of one year), there will be a need to respond to user comments on the validity and adequacy of the model. The model must perform accurately and efficiently.

Proposed Research: Develop an upgrade of the TNM that corrects user-identified deficiencies in the model. This upgrade will require extensive communication and coordination with users after TNM's release. The upgraded release of TNM will revise program elements which are functioning incorrectly and adjust the accuracy of model algorithms, where necessary.

Urgency and Payoff Potential: This is a necessary component of new model development. Completion of the upgrade will allow the full benefits of the new model to be realized.

Cost: $150,000
Duration: 1 year

Title: Reduction of Tire/Pavement Noise

Problem Statement: The tire/pavement interface is a primary cause of highway traffic noise. Variations in pavement types may have a pronounced effect on the noise source levels. Little research has been done within the continental United States to evaluate a reduced noise pavement.

Proposed Research: Tire/pavement noise is the subject of a current NCHRP synthesis study. Based on the conclusions and recommendations of this study, further research will be pursued to address the seeming conflict of maintaining safety and durability in pavement design with designing a reduced-noise pavement. This could include field testing of both domestic and foreign pavement designs.

Urgency and Payoff Potential: The public is becoming increasingly sensitive to the high level of noise from current standard pavement designs. The development of a reduced-noise pavement can reduce the area of potential noise impacts adjacent to highways and may reduce public annoyance with the tire/pavement component of highway traffic noise.

Cost: $300,000
Duration: 2 years

Title: Investigation/Validation of Testing Procedures for Souud-Absorbing Barrier Materials

Problem Statement: Controversy currently exists in the highway traffic noise barrier field as to the proper test procedure for determining the coefficient of absorption for barrier materials.

Proposed Research: A review of testing procedures used abroad (Europe, Japan) where sound-absorbing materials are prevalent may, in itself, provide an answer. However, an important aspect of the testing procedure may currently overpredict the absorption and should be investigated. Does the frequency range of the current test match the actual highway traffic noise spectrum? Given the low frequency content of highway traffic noise and the relatively poor performance of most sound-absorbing materials at low frequencies, should weighting be employed to determine an overall absorption coefficient? The weighted absorption coefficient for any material could become a module for the FHWA TNM to allow the consideration of the spectral content of barrier reflections for sound-absorbing surfaces.

Urgency and Payoff Potential: A substantial number of sound-absorbing noise barriers have been constructed or are planned for construction. The fact that controversy exists among noise experts on the value of existing test methods for noise absorption will only add to a loss of state Department of Transportation (DOT) credibility with communities seeking noise relief that are unsure of the value of state DOT proposals for sound-absorbing barriers. This can result in project delays and increased costs to satisfy the communities. This research study will help state DOTs maintain credibility and can increase the accuracy of highway traffic noise prediction.

Cost: $150,000
Duration: 1 Year

Title: Development of Outreach Materials to Aid in Noise Compatible Land Use Planning

Problem Statement: As the growth of urban and suburban residential development continues, instances of development that are incompatible with existing noise conditions along highways continue to occur. As a result, highway agencies are continuously faced with requests for noise abatement from newly developed residential areas located in high noise environments. Little new information has been generated or compiled on successful efforts made by local jurisdictions to control and guide development. Similarly, there are no tools available that utilize state-of-the-art methods to enable highway agencies to be more proactive in encouraging local jurisdictions to consider highway noise in the land use planning process.

Proposed Research: Develop outreach materials (pamphlets, manuals, videotapes, etc.) that present concepts, methods, and procedures that may be used to incorporate noise compatible land use planning in the local growth and development process.

The outreach materials should, as a minimum, address the concepts and measures contained in the existing FHWA report "The Audible Landscape" and should contain specific examples of communities with noise compatible growth and development programs. The existing FHWA slide-tape presentation titled "Sound Planning" and the interagency report titled "Guidelines for Land Use Planning and Control" should also be used as guides in development of the materials. The outreach materials should be developed specifically for use by those directly involved with land use planning - local officials, planning staffs, private developers, and the general public.

Urgency and Payoff Potential: The lack of guidance and information on successful examples of noise compatible land use planning in local growth and development programs can help foster incompatible development along highways. As state Departments of Transportation implement highway improvements, vast noise abatement programs must be included in areas of incompatible development. This research will provide the partners directly involved in local growth and development programs with tools to effectively plan for new development adjacent to highways. This will lessen the need for costly noise abatement as part of highway improvement projects, saving millions of dollars annually.

Cost: $250,000
Duration: 1 Year

Title: Transportation Noise Prediction Model

Problem Statement: To address noise concerns and issues in areas with intermodal transportation activity, there is a need to develop a multi-modal transportation noise prediction model.

Proposed Research: An interface/linkage between existing aviation noise prediction and highway traffic noise prediction models and future rail/transit noise prediction models will be developed to produce a comprehensive prediction model that will be fully multi-modal in scope and output. Model functionality and appropriateness of noise metrics in transportation noise analysis will be assured.

Urgency and Payoff Potential: This research will not be undertaken until noise prediction models for individual transportation modes have been released and put into use. A multi-modal transportation noise prediction model will allow for more informed decisions on analyses and abatement implementation in areas of intermodal transportation activity.

Cost: $150,000
Duration: 1 Year

Title: Investigation of Sound Propagation Over Irregular Terrain

Problem Statement: Most propagation routines neglect the effects of small scale roughness. Recent studies have indicated that small scale roughness, where the characteristic length of the roughness is smaller than the acoustic wavelength, can have a dramatic effect on propagation at grazing and near grazing angles of incidence. Such conditions are common in highway noise applications. These same studies have further indicated that rough surfaces can be acoustically modeled as though they were smooth with a modified surface impedance. In principle, the newly developed Traffic Noise Model (TNM) could incorporate surface roughness by including many terrain lines at slightly different elevations but this procedure would be computationally prohibitive and may not properly model the physics of the problem. Finding an analytic solution to the problem would speed computations and possibly improve accuracy.

Proposed Research: Research is proposed to better understand the effects of irregular terrain on highway noise propagation at distances of up to a kilometer. This research would seek to incorporate these effects into the latest propagation models and measurement methodologies. The following tasks are proposed to accomplish the goals of this research.

1) Perform measurements of noise levels at varying distances and heights from the vehicle path along with data of surface height profiles and impedance parameters (flow resistivity, etc.). The site geometry should be nominally level and open such that only the ground effect and geometrical spreading affect the propagation. The atmosphere should be still and data on wind speed, wind direction and temperature will be recorded so that atmospheric effects can be discounted. Removing atmospheric effects and geometric spreading from the analysis will leave the ground effect, including roughness, as the only remaining variable in the problem.

2) Using the measured data from task #1, along with data from other relevant studies, a prediction scheme will be developed which can be incorporated into an updated version of the TNM.

3) Perform validation at 2 "real world" sites along existing highways utilizing the same method and setup as used in task #1.

4) Using the prediction scheme developed in task #2, identify if surface roughness could be intentionally included in construction as a new mitigation technique.

5) Generate a final report documenting the measurement, prediction, validation procedures, analysis and results.

Urgency and Payoff Potential: Funding this research would provide information for the new TNM which would improve prediction accuracy at greater distances from a highway than is currently possible. This refinement to the model would increase the credibility of the

analysis to the public and provide a more complete picture of noise impact. Including surface roughness in an analytic manner, rather than through the use of terrain lines would improve the computational speed of the TNM. The research may also yield insight into a new mitigation technique, that is, including surface roughness in highway designs as a means of decreasing sound levels.

Cost: $250,000
Duration: 2 years

Title: Field Evaluation of Reflected Noise for Sensitive Receptors Across from a Non-Absorptive 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. Conventional wisdom suggests this is a social phenomenon not associated with the physical sciences. However, the consistency and repetition of complaints suggest that physical theory may not be consistent with reality. Comprehensive studies of noise level magnitude, annoyance image events (L10 - L90), 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).

Proposed Research: Several state Departments of Transportation 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 DOT's, 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 1000 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, e.g. wind speed and atmospheric stability, should be maintained during data collection. Using annoyance metrics to identify image events and 1/3 octave-band frequency analysis and meteorological data, traffic noise source and reflected spectra should be analyzed for the presence of an anomaly in actual conditions other than those currently predicted by the methodology. The analysis should identify whether or not a measured shift in 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, surface roughness, and vehicle type. A technical report should be prepared to present the findings.

Urgency and Payoff Potential: Community acceptance of noise barrier construction and state Department of Transportation credibility are seriously eroded by media reports of noise barrier reflected noise issues. The ability to logically and rationally explain the "reflected noise phenomenon" will greatly enhance State DOTs' credibility with the general public and help dispel community fears about noise reflected from barriers.

Cost: $200,000
Duration: 1 year

Problem Area: TRANSIT NOISE AND VIBRATION

Title: Transit Vibration Criteria Study

Problem Statement: There is significant proliferation of light and heavy rail transit systems within heavily populated areas. Introduction of new systems often involves aligning track near residential and commercial structures, often requiring costly mitigation to avoid adverse vibration impact. Criteria for human exposure to rail transit ground vibration are available in ISO and ANSI standards and are presented in the FTA Guidance Manual. Assessment involves measurement of vibration levels in third-octave bands generally from 1-80 Hz. The measured vibration levels are compared to either frequency-dependent band limits or summed over a frequency bandwidth. However, the Guidance Manual recognizes that movement still exists in the use of vibration descriptors. Measurement practices are not as standardized as they are for airborne noise evaluations, e.g., measurement averaging (exponential vs. linear) and averaging time are unspecified, band level limits and overall limits both are considered, and frequency bandwidths other than 1-80 Hz are often used. There is a need to further standardize measurement practices to quantify vibration exposures with metrics that reasonably predict human response (preferably in terms of a single-number vibration descriptor to simplify the evaluation and reporting of exposures). Finally, the criteria for mitigation need to be reviewed.

Proposed Research: A comprehensive attitudinal survey should be conducted parallel with measurements of 1/3 octave band vibration levels and overall A-weighted sound levels. The tests should include exposures from light- and heavy-rail transit, railroad, and highway truck and bus passbys of various frequencies. Measurement locations should include outdoors and indoors in structures of various types. The results of the survey and measurements should be compared with applicable criteria. A technical report should describe the results of the attitudinal survey, vibration and noise measurements, event frequency and duration, and should compare results with existing criteria.

Urgency and Payoff Potential: The avoidance of vibration mitigation using floating slabs, ballast mats, or other measures, would be a substantial payoff. However, the greater return on this research effort would be the ability to align rail systems closer to sensitive receptors with confidence that vibration problems would not result.

Cost: $300,000
Duration: 2 years

Title: Wheel Squeal Abatement

Problem Statement: Wheel squeal is generated when a rail car rounds a curve of tight radius. Modern heavy rail systems are usually designed such that revenue track is of sufficient radii that squeal is unlikely to occur. However, light-rail systems must often follow existing urban streets and tight radii cannot be avoided. System-wide control of wheel squeal may be needed for these systems. Heavy rail systems may experience wheel squeal in maintenance yards where selection of curve radii to prevent squeal is impractical. For these systems location-specific squeal controls are desirable. System-wide squeal control may be obtained by wheel damping devices of varying effectiveness and cost. Lubricants delivered by vehicle-mounted and wayside applicators of various design have been proposed. While grease lubrication has been used successfully by some properties, concerns exist regarding impacts on vehicle traction and safety which have prevented implementation by some transit agencies. Compilation of grease lubricant experience is needed to assess the legitimacy of these concerns. The effectiveness of these lubricants in controlling squeal, and the operational circumstances in which a particular design would be appropriate, should be investigated. In addition to a rigorous evaluation of the performance of these products, an examination of the practical impacts on operations, safety, and secondary impacts (e.g., soil contamination by the lubricant) is needed.

Proposed Research: The product of this effort should be a manual covering all aspects of the generation of wheel squeal, the various products and methods available for eliminating the problem, the effectiveness of these products and methods, and other considerations (such as safety, operational issues, and costs) in the selection of a systemwide or site-specific approach to the mitigation of wheel squeal. On the question of the effectiveness of the various products, especially the newer vehicle-mounted lubricators, it is expected that actual experimentation will be needed to supplement the available data gathered from transit agencies that have experience with some of these techniques.

Urgency and Payoff Potential: Planning and final design of numerous light rail systems and extensions is currently underway, including systems in Salt Lake City, Denver, San Diego, Portland, Baltimore, northern New Jersey, Sacramento, Milwaukee, Seattle, and others. Wheel squeal in the populated urban areas where these systems will be partly or entirely located is a major concern in the development and design of the system. In some cities, systems have had to be retrofitted with devices to control squeal where the original design did not anticipate the problem and the severe public reaction to the problem. A manual on all aspects of wheel squeal would provide invaluable information for rail transit agencies. The payoff would be significant and the need is immediate.

Cost: $150,000
Duration: 1 Year

Title: Warning Signal Assessment and Control

Problem Statement: New rail transit systems across the U.S. are creating increasing numbers of at-grade rail-and-roadway intersections. Transit vehicle-mounted warning horns and fixed wayside crossing signals are necessary for safety but can be a source of annoyance to surrounding residents. Compilation of data regarding warning signal safety requirements, noise emission levels, and reduced-impact alternatives is needed to assist transit system designers and operators. New technologies for effective warnings at reduced community noise impact need to be identified for development. Currently, warning signal exposures are evaluated with respect to the same impact criteria as used for line operations--noise sources of considerably different character. Review of the suitability of these criteria is desired to assure that warning systems are appropriately designed.

Proposed Research: Perform literature review that examines warning signal usage requirements/regulations,

documented noise impacts, and mitigation strategies attempted and their results. Perform an attitudinal survey of community response to warning signal exposures along with sound level measurements quantifying the corresponding noise exposure. Define possible mitigation measures deserving further development. Prepare report of findings and recommendations.

Urgency and Payoff Potential: The tradeoff at issue here is between the safety of at-grade roadway crossings of transit rail lines and the severe noise impact of a warning device on the surrounding community. Transit planners and designers need as much information as possible to make recommendations that ensure proper balance between two very important but conflicting objectives.

Cost: $100,000
Duration: 12 Months

Title: Transit Vehicle In-service Noise Emission Levels

Problem Statement: Rail vehicle noise emissions are known to depend strongly upon wheel and rail conditions. Vehicle sound levels may increase 10 dB or more with the presence of wheel flats or rail corrugations. Most data available for transit system design are for vehicles with new wheels and trackwork with new rails; thus, noise mitigation features—such as noise barriers—that are designed based upon these data may be inadequate after a period of revenue service operations. Understanding of typical in-service vehicle noise emission growth is needed to guide the design of noise abatement treatments with a margin of safety to assure that noise receptors are adequately protected throughout the life of the transit facility.

Proposed Research: Review the literature to categorize rail car types and configurations, and track conditions with respect to noise emissions. Define significant maintenance parameters (e.g., age and time since last wheel truing/rail grinding). Design vehicle noise emission test sample based upon railcar categories and maintenance parameters. Conduct railcar noise emission testing.

Urgency and Payoff Potential: The rail transit vehicles being manufactured for the newer rail systems being built in the U.S. are designed with fairly tight noise specifications. These specifications and new vehicle testing have been used in developing the FTA's guidance manual, *Transit Noise and Vibration Impact Assessment*. As the newer systems and vehicles age, it is not known how much deterioration will occur in their noise profiles. Older rail transit technologies have significantly different noise characteristics and cannot be used to estimate the effect of age on the newer systems. A limited study indicates that the FTA manual may result in estimates that are 1 dBA or more too low. The result may be inadequate protection of noise-impacted communities after several years of operation of the new rail systems.

Cost: $150,000
Duration: 1 year

Title: Computer Module and Database for Calculating Fixed Guideway Transit Noise

Problem Statement: FTA has published a manual on transit noise impact assessment that is useful in environmental impact assessment and preliminary design of rail transit systems. However, there is no standard noise model for use in the detailed final design of mitigation elements such as noise walls. With the advent of the Federal Highway Administration's Traffic Noise Model (TNM), the foundation for an accurate overground prediction model has been developed. Relatively minor changes to the algorithm of TNM would be required to allow its use in transit system design while ensuring consistency with the FTA guidance.

Proposed Research: The objective of this research would be to: (1) design and develop a computer module for computing noise due to guided transit vehicles; and (2) develop a reference noise database that, coupled with the computer module, can be incorporated into the FHWA TNM.

Cost: $300,000
Duration: 24 Months

OPERATIONS & MAINTENANCE

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BACKGROUND PAPER

The importance of transportation operations and maintenance (O&M) practices is often overlooked, including O&M practices which affect, or are affected by, environmental issues. Furthermore, the importance of maintaining a transportation program that is appropriately protective of human health and the environment is becoming more and more critical as public and administration-level awareness of waste management and other environmental issues continues to increase. As a result, transportation O&M program managers must be increasingly informed on environmental issues such as regulatory requirements and changes, technology innovations, pollution prevention and waste minimization concepts, and risk management approaches to decision evaluation and implementation. Of particular importance regarding legal and regulatory constraints on O&M practices are: the Resource Conservation and Recovery Act (RCRA); the Emergency Planning and Community Right-to-know Act (EPCRA); the Toxic Substances Control Act (TSCA); the Clean Air Act; the Clean Water Act; the Safe Drinking Water Act; the Pollution Prevention Act; the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA); the Hazardous Materials Transportation Act; and, the Occupational Safety and Health Act (OSHA). Of equal or more importance are the state equivalents to many of these laws/regulations which exist and may even be more restrictive than their federal counterparts.

Future research should be developed to help transportation O&M managers more efficiently and effectively deal with the numerous regulatory requirements and the very significant resource demands associated with being a good environmental steward. Such research can have the immediate benefit of synthesizing and sharing the different expertise and lessons learned from the hundreds of transportation agencies in the United States as well as other organizations that are confronted with the same or similar issues. Additionally, this research could assist in the development and implementation of specific new improvements in O&M practices and/or materials that better address environmental considerations.

Identifying opportunities to reduce, recycle or eliminate potentially harmful byproducts that must later be treated and/or disposed of is often the most cost-effective way to minimize adverse impacts and future liabilities associated with the generation of environmentally harmful wastes. Recent research shows that the avoidance of waste generation and discharge not only saves the direct costs of disposal and/or remediation, but it can also achieve substantial savings in costs associated with permitting, reporting, compliance and liability. Where complete elimination of waste is not possible, innovative technologies or practices may offer the best means of at least reducing environmentally damaging material wastes.

Recently, numerous success stories have been reported by private industry and at government/military facilities showing that simple changes such as recycling programs or substituting reusable or more environmentally benign materials for more hazardous materials can reap significant long-term savings. This has been shown through the use of life-cycle cost evaluation of alternative materials and practices that, although they sometimes result in a larger up-front investment of resources or reduced efficiencies, produce substantial savings over their program life when issues such as regulatory compliance and ultimate removal and/or disposal considerations are factored into the comparative analysis. Life-cycle approaches have been used successfully by many transportation agencies to decide which capital infrastructure improvements are preferable, but application to transportation O&M prac-

tices and materials has been less comprehensive and consistent and represents an area where further research and information sharing could provide great benefit. Promising examples include improvements in vegetation use/control, beneficial reuse of contaminated materials, pavement and/or other structural materials, and substitution for or deletion of the use of chemicals in transportation infrastructure maintenance.

Currently, the facilities design and personnel training/education components of many transportation O&M programs do not properly incorporate regulatory and other environmental considerations, often resulting in operational inefficiencies and O&M facilities that quickly become functionally obsolete. In the transportation arena, O&M personnel lag behind their counterparts in private industry and elsewhere in terms of how they implement environmental safeguards and how they plan for and deal with chemical materials storage, use, disposal and reporting. This is because these counterparts have invested significant time and money into environmental training and upgrade programs and have developed many improvements in their O&M practices. Greater education of transportation O&M managers and facilities planners regarding the applicable requirements of RCRA, OSHA, EPCRA, the Clean Water Act, etc., would likely produce similar savings and improvements. Transportation research for this purpose and for the purpose of using synthesized experiences and successes to develop prototype O&M facilities designs and training/education programs could therefore yield significant benefit.

O&M research could also be extended to include the development of enhanced tools for field maintenance and landscaping. In particular, the mapping capability of GIS could be extended to delineating sensitive vegetation areas along highway rights-of-way. This GIS application would best be developed with the direct input of field personnel. Mapping sensitive areas would help to eliminate the inadvertent cutting of a specific vegetation as well as help to assess overall maintenance, i.e. cutting areas for estimating maintenance schedules and budgets. Other application of GIS tools should be explored for their application to O&M issues.

RESEARCH NEEDS STATEMENTS

Title: Analysis and Improvement of BMP Methodology

Problem Statement: Maintenance practices and programs are highly individual even within a single state. At the same time, there is a thread of commonality among various maintenance units. Also, many environmental impacts are acquired by maintenance after a facility is in place. Best management practices (BMPs) are current innovative practices or combinations of practices that utilize technological, economic, and institutional guidelines or policies to mitigate routine or unusual maintenance problems in a manner compatible with environmental quality goals. These are used as current benchmarks. BMPs have been used successfully with a number of maintenance practices or programs that ensure they perform as originally designed. Often, BMP performances are compromised by failure to devise an effective maintenance practice. Currently, there are no systematic means for sharing these practices.

Proposed Research: Processes need to be developed to continually build upon and improve current BMPs using CQI principles. Build upon NCHRP Project 20-5, Topic 28-01; this describes the present but not the achievable level of maintenance quality:

(1) Assemble a list of current BMPs, together with requirements for success or reason for failure.

(2) Assess cost effectiveness for individual BMPs.

(3) Determine awareness training and education needed for implementation of BMPs considering both engineering and environment.

Examples of BMPs include but are not limited to:

(1) Frequencies of runoff BMPs and their effect on resultant pollutant removal. These are acutely affected by maintenance practices that ensure they perform as originally designed to establish a database of existing highway runoff within a watershed or geographic province.

(2) Street sweepings are typically disposed of in landfills as daily cover. Developing a policy to reuse this material would be both beneficial and cost effective.

(3) Loss of fine materials from unpaved roads and their drainage areas results in pollution from both dust and sediment.

PRODUCTS:

(1) A detailed report establishing a current data base for current practices and suggestions for periodic updating, and

(2) A pilot test in 2-3 states in cooperation with the state DOT.

Cost: $150,000
Duration: 24 months

Title: Environmental and Safety Impacts of Snow and Ice Control

Problem Statement: Annually, approximately $1.5 billion is expended in the United States on ice and snow control. One-third of this cost, or approximately $500 million is expended on materials, primarily salt. Effective snow and ice control is a significant expense and major problem for states, counties, and cities in the 38 snow belt states. Inadequate application of chemicals and abrasives can result in loss of mobility, increase in injury, death, and property damage from accidents, and a major negative impact on the area's economy. Over-application results in needless cost and undesirable effects on air and water quality and degradation of infrastructure and personal property. While anti-icing and deicing chemicals have been used in winter maintenance for many years, the optimal application rates of these chemicals and materials for different weather conditions, temperature, road surfaces, and desired level of service have never been determined in a quantifiable manner.

Proposed Research: Research should focus on: 1). best method practices for determining the most appropriate snow and ice control response; 2). existing and potential equipment improvements, which include better liquid, dry and pre-wetted chemical and material delivery patterning, more precisely controlled application rates, GIS/GPS adjusted rates related to pavement types, current and forecasted road conditions with real time friction and thermal readings, and methods for the rapid changing of the chemical and abrasive mix being delivered; 3). results of state, national and international research, i.e., SHRP and FHWA test and evaluations based on snow and ice control programs for better storm management practices and reducing the need for chemical and material application rates; 4). SHRP snow fence research, the Kansas City, Missouri airport experience during several years with tall native grass and Great Plains shelter belt research for reducing mechanical and chemical snow control costs; and 5). relationship of winter maintenance to traffic safety. Information sources for the study should include a literature search using TRIS and other domestic and international databases. Contractor will evaluate technology and assess cost and value received. Technology transfer is important to the effective and efficient implementation of these research results. Contractor should provide fact sheets summarizing the important elements of the research and a video of approximately 20 minutes duration explaining the results and benefits of improved snow and ice control practices.

Cost: $225,000
Duration: 18 months

Title: Environmentally Sensitive Design for Highway Facilities

Problem Statement: Many facilities required in transportation operations and maintenance have evolved to the present by expansion, modification, and adaptation of design and materials common to several years ago. At this point most are inefficient with respect to size and energy consumption for heating, lighting and ventilation; have environmentally unsafe or inadequate capacity for storage, treatment, or disposal of recyclable items, sewage, and other waste; provide inadequate salt storage, loading and runoff containment; include aging, difficult to inspect underground storage tanks; and lack suitable, dedicated storage for solvents, herbicides or potentially hazardous materials.

Proposed Research: Building on TCRP SYNTHESIS 7, Transit Maintenance Facility Design, develop typical design alternatives for small, medium and large operations and maintenance facilities that provide safe, efficient work space, vehicle and equipment storage, environmentally safe storage and containment systems for spills or rinsate from cleaning operations; include reusable, recyclable and recycled building materials; identify environmentally low impact heating, cooling and lighting alternatives, biological treatment systems for waste water that can meet EPA standards; and develop design criteria for environmentally safe underground fuel storage and investigate alternative above ground storage or procurement from commercial sources.

Cost: $200,000
Duration: 12 Months

Title: Roadside Vegetation Management: Ecological/Economic Solutions

Problem Statement: Traditional vegetation maintenance methods are often environmentally insensitive,

unsafe, and costly. Budget and staff reductions dictate reduction of costs and labor spent on vegetation maintenance.

The problem could be solved through ecological principles that are environmentally sensitive, safe, and less costly, i.e.:

- revegetation with regional native plants;
- reduced mowing that allows natural revegetation;
- ecological management and protection of existing natural remnants; and
- targeted herbicide control plus biocontrols (insects or planting natives).

Proposed Research:

A. Identify remnant (naturally occurring) grassland and forest plant communities in each region (NW, CA, SW, Rockies, Midwest, NE, SE, South) that can be used as models for our vegetation management methods.

Use these plant community models to develop vegetation management strategies that meet safety, environmental, esthetic, and economic maintenance goals.

1. Reduce cost of vegetation maintenance nationwide.
2. Cost comparison of ecological and traditional methods.
3. Reduce herbicide, fertilizer and irrigation use in vegetation management.
4. Define vegetation strategies at "regional" levels of U.S.A.
5. Determine native warm and cool season grasses for roadside application in each region.

Cost: $150,000
Duration: 12 Months

B. Explore consequences of reduced mowing over time (working with natural succession or encroachment) in non-operational zones of right-of-way.
1. Determine timing of consequences in forested and grassland environments i.e. weed invasion, view closure, 4" caliper trees in clear zone.
2. Determine how seldom mowing or alternative methods are needed to respect safety needs.
3. Define what pest species should not be allowed to encroach and will be spot sprayed or biocontrolled. (information exists)

Cost: $150,000.00
Duration: 60 Months

C. Analyze existing roadside vegetation to determine locations throughout states of existing native vegetation remnants to be protected.
1. inventory existing vegetation to develop vegetation management plans.
2. compare results of hands-off, reduced mowing, spot spraying, burning, and biocontrol methods.
3. define method best suited to region and plant community types.

Cost: $350,000
Duration: 36 Months

Topic: Environmental Protocol Development For Product And Waste

Problem Statement: Public opinion and perceptions regarding the protection of the environment now demand that sound management practices be incorporated into the culture of all levels of state and federal transportation departments. The majority of materials transportation departments handle contain complex chemical mixtures. Environmental data regarding these materials deal almost exclusively with the effects of individual chemicals. In order to design sound management practices transportation departments must be able to have a reasonable assurance that the materials being used and wastes reused minimize future environmental impacts and liabilities. Protocols do not exist to quickly and inexpensively evaluate the relative environmental impacts of these materials. Lacking these protocols long term disposal, recycling, reuse options cannot be compared to existing risks transportation departments take during normal operations. Lacking this risk information environmental and financial management decisions are individually developed, costly, and the results are highly speculative.

Proposed Research:

1. Develop a scientifically defensible, rapid, cost-effective biological/chemical protocol that allows environmental risk management decisions to be made that limit environmental impacts from materials to equal to or less than the risks currently accepted by transportation departments.

Cost: $150,000
Time: 1 year

2. Develop an easily operated computer program that uses readily obtainable inputs to analyze potential environmental risks and places monetary value on these risks such that management decisions can be made by transportation departments regarding material usage and/or waste disposition.

Cost: $150,000
Duration: 1 year (following results from #1.)

3. For standard transportation wastes, develop a computer program that will identify areas within the production of each waste where pollution prevention/waste minimization strategies can be implemented to reduce waste, recycle wastes, or eliminate wastes.

Cost: $150,000
Duration: 1 year (concurrent with #2.)

SOCIAL & ECONOMIC IMPACTS

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BACKGROUND PAPER

The current public policy debate is often dominated by the National budget. Every claim upon that budget, including those of transportation, must be carefully justified and balanced against other competing needs. Recently, pressure has come to bear on federal-aid highway funds, and the associated earmarked gasoline taxes, as a means for alleviating shortages in other areas of the budget or reducing the overall tax burden. Similarly, federal assistance for mass transit, rail, air, and shipping has come under increasing scrutiny, and in many cases, funding has been reduced. In this climate, transportation investments must be justified economically, and the benefits of transportation must be made clear to policy-makers and the public. Transportation must enhance economic growth while it moves people and goods.

Public pressures lead to other issues associated with the environmental effects of transportation facilities. A growing concern has been the impact of transportation policy on disadvantaged and inner-city communities. There is an imbalance in how projects are economically and socially justified. These "environmental justice" concerns must be effectively addressed in future transportation policy decision-making and facility proposals. Some argue that, while the primary beneficiaries of highways have been suburban car-owners, their direct impacts have impinged mostly on inner-city communities. This type of situation has led to the consideration of environmental justice as an important component in assessing the impacts of federal projects. Others assert that lack of funding for mass transit has denied inner-city residents access to jobs that have tended to locate on urban peripheries. This is an overall policy consideration that nevertheless has implication for environmental justice.

Other environmental concerns surround air quality and the effects of transportation on land development and the environment. The Clean Air Act Amendments of 1990 have resulted in initiatives creating incentives for employers to reduce dependency on single-occupant motor vehicles, as well as encouraging Transportation Demand Management (TDM) strategies aimed at affecting traditional transportation behavior and trends. The spread of suburban development and its environmental effects have also become important public concerns. The connection between transportation facilities and land development is intuitively obvious to a public that has become increasingly impatient with the deterioration of America's landscape and environmental resources.

Transportation professionals are asked to plan for and defend transportation. Unfortunately, they often lack the analytical tools to comprehensively evaluate and adequately explain their proposals, and, as a result, sometimes must face public opposition that cannot be effectively ameliorated. Each of the major transportation issues outlined above, therefore, demand that analytical and public interaction tools be developed to effectively explain and defend reasonable proposals.

Transportation research in the area of social and economic impacts must address these concerns. One of the key research initiatives has been underway for several years: to determine the effect of transportation investment on economic expansion. The research consensus to date is that transportation investment has a positive influence on productivity and economic growth. However, the magnitude and specific mechanisms of that influence are far from clear. Needed now are better data bases and tech-

niques to allow the identification of more precise quantitative relationships between transportation investments and economic change at several levels: national, regional, metropolitan areas, and local. A clear sequence of causality must be established between development and maintenance of transportation facilities on the one hand and the creation of jobs and wealth on the other. Predictive models are needed that can effectively persuade policy makers of the economic benefits of transportation facilities and convince the public as well.

In the area of environmental justice, research is needed to determine how transportation planners can better meet the needs of disadvantaged communities while carrying out their charges to efficiently move people and goods and enhance economic development and productivity. This is particularly important given the mandates of Executive Order 12898 and EPA's recently published draft document entitled *Guidance for Incorporating Environmental Justice in EPA's NEPA Compliance Analyses*. There are many examples of transportation facilities which have successfully met this challenge. These must be identified, and the planning and permitting processes recorded so others can benefit from the experiences of successful projects. Better techniques are required to allow the identification of cohesive communities in the path of proposed transportation facilities. Research is needed to identify the most effective mix of mitigation policies when such situations are encountered. Transportation planning must also effectively address the decline of America's urban centers. Research must be conducted to determine the best and most efficient means to provide transportation facilities to disadvantaged communities, so they do not fall further into economic isolation and social disintegration.

The Clean Air Act Amendments of 1990 mandated the formulation of Employer Trip Reduction (ETR) Plans and Transportation Management Agencies (TMAs) throughout the nation. These measures have been in the process of implementation for several years now, and a great deal of data concerning the effectiveness of various Transportation Control Measures (TCMs) has been gathered. Research is now required to evaluate this data base to determine the most effective strategies to increase average passenger occupancy (APO). Many employers have developed incentive plans to encourage people to use mass transit or car pools. The most successful incentives must be identified, along with the circumstances which lead to their success. Means must also be found to extend TCMs to smaller employers and the general population.

Air quality improvement is also bound closely with the issue of land use-transportation interaction. There is still no consensus regarding how transportation facilities influence land development. Many hold that transportation facilities are built in response to land development, while others argue that transportation facilities stimulate development. The truth lies somewhere between these two positions, and varies with local and regional geography. Continued research is needed to precisely define the linkage of land use development and transportation facilities. Comprehensive case studies and before-and-after studies are needed. There have been many excellent anecdotal and qualitative studies of this nature, but they do not offer the precision that is required. The quantitative studies have generally lacked sufficient data resources to be fully effective. These data resources must be developed to further research this field. The volume of construction of transportation facilities in the last four decades has been of such magnitude that it is difficult to believe that there is insufficient data to fully evaluate some carefully selected projects for their impacts on land use development. The huge volume of studies that have been conducted in the field must be thoroughly evaluated to identify the techniques and approaches of most value. Projects suitable for before-and-after studies must then be identified, and comprehensive data gathered to conduct definitive analyses. In the meantime, currently planned projects must be studied with the intent of formulating the data resources required for future before-and-after studies.

Transportation planners and public officials responsible for implementing transportation policies need the tools to more effectively evaluate the impacts of proposed projects and to properly inform the public of these impacts, both positive and negative. Over the years, many research studies have been conducted concerning methodologies for assessing the economic, land use, and social (i.e., *socioeconomic*) impacts of transportation facilities. Most of these methodologies have remained theoretical because they have proven to be beyond the data and analytical resources available to transportation agencies. With the recent rapid advances in computing power and modeling capabilities, it should be possible now to develop analytical techniques that can define more precisely the socioeconomic effects of transportation facilities. For many years, since the passage of the National Environmental Policy Act of 1969 (NEPA), the emphasis in environmental studies has been on the biological and physical impacts of transportation facilities, while the human impacts have often been treated less comprehensively. At present, there is increasing interest in socioeconomic impacts, and many assert that impacts on humans should be studied in as much depth as impacts on plants and animals. In this regard, research into the development of appropriate methodologies and procedures for assessing "quality of life" impacts as viewed by the general public would serve to enhance public understanding of critical socioeconomics issues.

Research to develop more effective socioeconomic impact assessment techniques should proceed along several parallel avenues. First, the analytical techniques that have already been developed, but under-utilized, should be evaluated with the goal of identifying the most promising techniques. These techniques should then be tested on transportation project environmental impact assessments. Second, data bases must be developed to fit the methodologies. Major advances have been made in collecting and organizing socioeconomic data during the last ten years, ranging from remote sensing and Geographic Information Systems (GIS) to CD-ROMS and extensive U.S. Government data bases of many types. An effort should be undertaken to evaluate and collate these data bases, identifying those which will be most useful in socioeconomic impact assessment. Finally, new socioeconomic impact assessment techniques should be developed both to cover the gaps in existing knowledge and to take advantage of new analytical techniques.

These research initiatives must be accompanied by efforts to make the new analytical tools available to under-funded public agencies. There must be an emphasis on simplicity and transparency of technology, to assist officials who are hard-pressed to explain their conclusions to local policy makers and members of the public. Also, improved techniques for communicating the results to the public must be developed. New tools such as multi-media presentations are becoming less expensive, less complex, and more effective for presenting information to the public. These types of tools must be adapted to the needs of transportation officials and agencies. Although a model or other methodology might be successfully developed to provide unerringly accurate results, if transportation planners cannot explain it to the public, the original research might as well have not been undertaken.

RESEARCH NEEDS STATEMENTS

Title: Environmental Costs of Deregulation and Privatization in the Transport Sector

Problem Statement: Two common types of institutional arrangements in transportation are deregulation and privatization. Deregulation is often seen as a way of introducing market factors into transport operations by eliminating governmental regulations on entry (who may provide the transport service), exit (abandonment or termination of the service), and pricing (freedom to change fares and tariffs). Privatization in the transport sector is usually viewed as a way of providing transport facilities or services in the absence of public sector funding. Each of these activities generates environmental costs, but they are rarely discussed and hardly ever assessed. This proposal seeks to establish methods to assess the environmental costs generated by deregulation and privatization.

Deregulation began with the Rail Revitalization and Regulatory Reform Act of 1976 for the rail freight sector and the decade that followed saw the deregulation of airlines, intercity bus service, and motor carriers. While some attention was given to early actions, particularly those involving abandonment of service, it is not apparent that such activities are assessed any longer. In many cases we have seen service withdrawn necessitating longer intermodal shipments of goods and longer, more polluting motor vehicle drives for passengers. In other cases the modal industry has set up service configurations, e.g., the hub and spoke system, that have created significant environmental pollution for hub cities in comparison to any normal air traffic these places would have generated in the absence of a hub. Looking at the air passenger industry, their hub and spoke system generates significant costs for consumers and could generate excessive environmental costs in comparison to other systems of service, i.e., minimizing environmental costs is not their objective. Similar problems may exist for other modal sectors as well.

Privatization of the transport service sector should not generate more environmental damage than public sector provision. However, we are uncertain if low use of a facility, such as a toll road, would result in operators lowering tolls to generate higher income and as a result additional travel and related impacts. There also seem to be some questions as to the level of environmental overview that states have over privatization types of projects.

Proposed Research: The proposed research would examine all of the major deregulation sectors (rail, airlines, motor carriers, and intercity buses) and assess the environmental costs of deregulation that have occurred to date. This would be a retrospective study that would look at the environmental costs of service in 1974 (using current dollars) in comparison to the cost of using replacement modes since termination of the former service. To this end the researchers should identify the rail abandoned, airline services withdrawn, motor carrier routes canceled and intercity bus service curtailed or abandoned, and assuming the same traffic level that existed in 1974 compare the environmental costs generated by substitute service provided by other modes (e.g., rail to motor car-

rier, intercity bus to private auto, and so forth). The research should also estimate the costs of a shift in the way service is provided if these appear to generate additional environmental costs, e.g., the shift from conventional intercity airline service to a hub and spoke system. The research should generate statistics on changes in these environmental costs and estimate losses to date. This research should also identify methods for states to use in making this type of environmental assessments for future deregulation projects.

Research on the environmental costs of privatization should begin with a comprehensive assessment of the extent to which privatized services are monitored by the states during the life of these projects including all aspects of route identification and planning to reconstruction. What practices are followed by the states? Are these governed by state law or regulation? Compile examples of best cases from an environmental perspective. Do procedures exist for identifying the environmental costs of lower fares or tolls in terms of increased traffic, congestion and induced travel? Inventory methods used to identify these impacts by the states, or if such methods do not exist, design a procedure to make such assessments and illustrate its use.

Cost: $600,000
Duration: 36 months

Title: Identifying Community Cohesion for Transportation Decision-making

Problem Statement: Consideration of proposed transportation projects and programs impacts on community cohesion has been required since the Federal-Aid Highway Act of 1970. With the renewed emphasis on social considerations, the lack of resources, and the emphasis on "letting date" deadlines driving State DOT's, there is a need to (1) help determine the existence of and (2) degrees of cohesion in a variety of community settings.

Because "significant" social impacts can drive the environmental documentation process, tools to help expedite such determinations are needed. Because community cohesion is a key element within FHWA's 23 USC 109(h) requirements and the transportation planning community has limited staff with social science training, a tool to at least identify, if not assess impact on community cohesion is needed.

Public involvement has been used as an indicator of community cohesion; however, it often motivates individuals with a vested interest in project specifics to participate. Groups of such individuals may not, in fact, accurately indicate the cohesiveness of the community. An objective tool is needed.

Proposed Research: Examine working definitions of community cohesion currently used by state DOT's, MPO's, and other relevant organizations. Develop a quantitative definition of community cohesiveness using statistical methods. One possible approach would be to identify some classical cases of cohesive communities and non-cohesive communities. Researchers could then use data available from the U.S. census (e.g., age of population, or housing, vacant housing units, income, and so forth) in a multivariate statistical technique such as discriminant analysis to translate these perceived groups into statistically different classes and identify mathematical rules for such assignments. Further analysis could reveal whether there are regional variations in "community cohesion."

In addition to the above and perhaps as a prelude to it, the researcher should identify similarities in definitions for varying types of communities; i.e., urban/rural, developing/declining, transient/stable, and new/established. Develop a list of "cohesion" indicators based on secondary data, and determine a priority of "best indicators." Apply the list across a matrix of community types. Test the accuracy/repeatability of the resulting indicator(s) of the findings on communities of known cohesiveness, identifying characteristics which are reliable indicators. Develop practical recommendations and conclusions on the use of the research tool within a context of the limited time, staff, and other resource constraints of MPO's and State DOT's.

Cost: $300,000
Duration: 2 years

Title: Establishment of a Framework for Assessing Trade-offs of Physical and Human Impacts on Transport Projects

Problem Statement: Transportation officials, environmentalists, and interested citizens recognize the need to have an effective transportation system for the movement of people and goods. With each project, however, comes the need to determine the extent of beneficial and negative impacts of the proposal on the natural environment and community before it is ultimately adopted and/or constructed. The decision to implement a project often results in a choice or trade-off between impacting natural resources (e.g., wetlands, endangered species habitat, or woodlands) or community and human resources (e.g., residential patterns, cohesion, or access).

Many practitioners and public officials however realize that they need information in an analytical format that will allow for the measurement, identification, and comparison of impacts of a transportation proposal. Often the decision to proceed with a project will require a choice of whether the human or natural environment is impacted. The rationale for selection may ultimately be political, however, it should be based on an analytical package of information giving sufficient attention to both physical and human impacts. The decision maker needs to be able to confidently address the basis for impacting one segment of the community over another. In most cases, the selection tends to favor the avoidance of the natural environment at the expense of the human community due in large part to the existence of numerous laws, regulations and guidance documents which provide protection for the natural environment. The need for an analytical framework that better balances our treatment of physical and human impacts is evident. However, presently the necessary tools and information do not exist.

Proposed Research: The research will involve an investigation of current measurement tools available for assessing transportation project impacts. The study will involve the collection of information from each state, or a representative sample of states, which will provide the basis for the identification of useful measurement tools and case studies to be utilized as examples for practitioners. These tools will be developed and refined sufficiently for applicability to various types of modal choices that impact both the physical and human environment. The research effort will identify important stakeholders and partners who may be involved in either or both the natural and human side of transportation impacts. The latter could include intergovernmental partnerships for further impact identification and verification. A framework to investigate life cycle analysis as a strategy for physical and human impact assessment will be developed to determine its relative value as a measurement tool in assessing these trade-offs. Potential data collection techniques to be used include, but are not limited to: literature review, identification and interview of community groups, regulatory agencies, resource agencies, and state and local transportation officials. Deliverables include: a study report (with an executive summary), a listing of recommended measurement tools that allow an identification and assessment of the tradeoffs between the physical and human environment.

Cost: $350,000
Duration: 24 months

Title: Methods and Techniques for Identifying and Measuring Disparate Impacts From Transport and Related Case Law History

Problem Statement: Minority and low income communities have suffered the environmental burdens of regional transportation development, local transportation systems, and transportation infrastructure. Examples include location of noxious facilities (diesel bus depot clustering), routing of toxic materials, highway development that broadens regional scope yet destroys the cohesion of a community, decrease in operating subsidies and ridershare, and lack of access to transportation modes. Recent applications of Title VI, NEPA, Uniform Act of 1970, ISTEA, and Executive Order 12898, highlight the lack of understanding and training in methods and techniques to identify and measure disproportionately high and adverse impacts (disparate impacts) resulting from transportation projects. There is also a lack of understanding case law history of Title VI and its boundaries. Specifically, since the passage of ISTEA and the signing of Executive Order 12898, state DOTs have expressed concerns over the lack of national guidance in effective public involvement methods and evaluation and mitigation of environmental justice community impacts.

Proposed Research: The proposed research includes: (1) Case law review of disparate impact issues in environmental and transportation related projects, (2) Survey of public agencies, private agencies, and grass root organizations to identify environmental justice issues in the transportation sector, (3) Survey of best use practices of methods and techniques used to identify disparate impacts in transportation projects, (4) Identification of mitigation strategies to avoid and minimize discriminatory community impacts, and (5) Identification of training needs at the national, state and local levels to comply with Executive Order 12898 and related existing federal laws.

Cost: $400,000
Duration: 24 months

Title: Identification of Methods and Techniques to Assess the Social and Economic Impacts of Transportation Projects

Problem Statement: In the past, the consequences of transportation investments on communities have often been ignored, minimally addressed, or introduced near the end of a planning process, reducing them to reactive considerations at best. This lack of adequate assessment has occurred despite long-standing requirements that agencies like FHWA conduct social and economic analyses of their

programs and projects. Title VI of the Civil Rights Act of 1964 and the Federal Aid Highway Act of 1970 (see 23 USC 109h) provide the basis upon which these types of impact assessments are done. In 1991, ISTEA further emphasized the need to address social and economic issues in planning phases as well as during project development. In 1994, EO 12898 further elevated the emphasis on assessing impacts on communities.

Recently, FHWA in conjunction with state and local transportation officials, prepared a Community Impact Assessment process which parallels FHWA's NEPA process. It identifies four important reasons for assessing the social and economic impacts of transportation projects. First, the assessment of community impacts supports sustainable livable communities; it promotes community values and thriving neighborhoods; and it contributes to general well-being. Second, the assessment of social and economic impacts helps ensure that transportation policies and investments embrace the concerns of neighborhoods and communities which leads to better decisions and greater acceptance of projects. Third, social and economic impact assessment helps coordinate and integrate independent plans for land use, local economies, and transportation to achieve common goals. Fourth, the assessment ensures that we must fulfill our obligation to achieve environmental justice through practices and procedures which do not discriminate.

A need exists to identify methods, tools, and techniques that will aid practitioners in assessing the social and economic impacts of transportation projects. In these days of limited resources, practitioners are in need of methodologies and tools to efficiently address the rising emphasis on social and economic impacts.

Proposed Research: The proposed research would be undertaken in two phases. Phase I would include a literature search and review of current research in the area of social and economic impact assessment. An annotated bibliography should be prepared of the available national and international literature. Simultaneously, a survey of State DOT's, MPO's, Federal-lands, and similar agencies would be undertaken to determine current methods and tools employed to assess the social and economic impacts of transportation projects and programs. Also identified during the survey should be the sources of information used (i.e. primary or secondary) in the analysis as well as who is responsible for collecting the information (i.e. consultants, staff, etc.). This information will be useful in assessing the efficiency and cost of data collection efforts for the various methods. The survey also should collect information on mitigation measures employed by the respondents to address social and economic impacts.

The literature and survey results will be used to identify key groups of best practices for social and economic impact studies. The impact assessment methods should be identified as appropriate for planning studies and/or detailed projects studies. Consideration should be given to identifying various methods dependent on project or program needs and the labor and cost intensity of the data collection needed for the assessment efforts. A series of case studies that utilize the best practices and tools identified from the survey and literature should be established. The case studies should cover a range of planning studies and project studies in various settings.

Phase II of the project would use the findings of Phase I to identify recognizable gaps in the tools and methods available for impact assessment. A work plan would then be prepared outlining how to develop the methods, tools and techniques needed to fill these gaps. This work plan would then be used to develop the approach to Phase II of the research.

Cost: $450,000
Duration: 28 - 48 Months

WATER QUALITY & HYDROLOGY

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BACKGROUND PAPER

Federal regulations on the one hand and decentralization/downsizing on the other have generated a collection of monitoring data, research results, and experience that has no central repository. The number one research need in water quality is to find an electronic home for this information easily accessible to all interested and regulated transportation professionals dealing with water quality. The second most pressing research need is the development of protocols that focus resources and concerns on the process and effects that have importance in the overall environmental management context. What methods do we use? How much monitoring should we conduct? How do we spend our scarce budgets and staff resources in order to be responsive to environmental protection and preservation?

Earlier generations of water quality research broadly identified these environmental concerns and began to quantify our technical understanding of some issues. These works looked for simplifications that were operational such as not having to be concerned if the ADT was less than 30,000 vehicles per day. The upcoming generation of research must focus more specifically on quantitatively assessing impacts and place them within a framework and perspective that meets the future, more detailed, needs of transportation planning. Research must be conducted to advance scientific knowledge in a way that will help our front-line practitioners as well as shape a policy that satisfies the demands of a changing regulatory environment and supports our national directive to integrate environmental responsibility and economic growth.

To achieve this, research that anticipates future issues arising from the new approaches being adopted by regulatory agencies that implement the intent of federal, state, and local environmental legislation should be advanced. As transportation officials must demonstrate compliance with federal and state permit requirements for transportation actions that affect surface water quality, groundwater quality, flooding, and streambank/shoreline erosion, they need to participate in the evaluation of these new regulatory approaches. The emerging regulatory methodologies for assessing these topics are based upon watershed and ecosystem management approaches.

The President's Clean Water Initiative presents the Administration's position regarding reauthorization of the Clean Water Act and makes specific recommendations with regard to watershed management, particularly with respect to the development of state programs. Similarly, the Interagency Ecosystem Management Task Force has developed a strategy for implementing ecosystem management which integrates ecological, economic, and social factors to simultaneously promote healthy ecosystems and sustainable economies. The USEPA predicts that there will be an exponential increase in the number of federal, state, and local organizations managing water resources on a watershed/ecosystem basis by 1999.

Many states and several NCHRP and FHWA administrative contracts currently support projects that are assessing surface water quality, groundwater quality, flooding, and streambank/shoreline erosion within a watershed/ecosystem framework. Upcoming research must respond to this trend by developing guidelines for consideration of transportation environmental issues within these new frameworks. And, with this in mind, research must bridge a growing gap between the existing science and technology database and regulatory demands–this gap can be narrowed with current information technology. Practicing transportation environmental managers, scientists, and engineers identify and better understand the expectations and requirements of federal and state regulators within their jurisdictions which may vary from one region

of the country to another. To assist state DOTs in preparing environmental documents, guidance manuals are needed that specify overall and unique regulatory concerns and requirements and how to marshal and apply our resources.

The fate and transport of a pollutant from its point or nonpoint source has long been a challenge to environmental scientists. Research is needed to develop guidance manuals on the application of existing fate/transport models to transportation-specific issues and to develop new models that address processes that are unique to particular transportation-related conditions. It is very critical that research needs to be directed on monitoring and modeling the fate and transport of transportation-related runoff and air-induced emissions with respect to water quality impacts. The modeling needs to expand upon the existing database of wet weather processes and stormwater runoff. The need to more accurately assess the impacts of stormwater runoff is particularly relevant and important to the concerns of transportation officials in view of court decisions whereby a state DOT was found in violation of the Clean Water Act for failing to control highway stormwater runoff. In addition, some states are now requiring assessments of the contribution of highway stormwater runoff to municipal separate stormwater systems for the purposes of obtaining National Pollutant Discharge Elimination System (NPDES) stormwater permits.

Important decisions regarding the future of individual transportation projects and overall transportation policy are based upon the interpretation of issues such as the actual consequences to water resources of a calculation that 50 tons per year of eroded soil originates from a transportation construction site. Or, how is this quantity related to impacts to receiving water turbidity per storm event? Similarly, what are the actual impacts to aquatic life of a runoff event mass loading of two pounds of total zinc? How is this quantity related to water quality criteria (now expressed as dissolved metal), biota tolerances, and physio-chemical reactions each of which are measured in terms of concentrations? Research is needed to produce operational guidance manuals for how to interpret data with respect to long-term and short-term impacts, including an evaluation of the limits of methodologies and the conclusions that can be drawn from them.

The likely increase in the use of alternative fuels, vehicle redesigns, and changes in manufactured materials makes it imperative to examine both the runoff and emissions characteristics of future vehicle use. In addition, with the greater utilization of rail systems and mass transit forecast for the future, research is needed on the stormwater runoff characteristics of these modes of transportation. To date, the research on runoff has concentrated on roadways.

The range of environmental impacts of transportation systems on water quality and hydrology is wide. There are direct and indirect effects from construction activities, systems operation, and the means employed to manage unavoidable impacts. Construction activities disturb surface soils and in-stream sediments. Watershed hydrology may be altered by channel relocation or the placement of obstructions to flow. Pollutants in surface runoff from facilities during operation are delivered to surface waters and infiltrate to groundwater. In addition, pollutants in air emissions are delivered to surface waterbodies and affect water quality. Best management practices to minimize impacts may or may not be successful. Which process and what activities are "hot spots" that need to be addressed?

Research regarding the means employed to minimize transportation-related impacts needs to be expanded. Transportation-related projects often have technological and financial constraints that require innovative solutions to mitigate predicted impacts. Transportation officials need access to an up-to-date assessment of the performance, constraints, and costs of implementing best management practices (BMPs) to make informed decisions. Many DOTs have indicated that they do not need more characterization studies, that they, in fact, prefer guidance on how to deal with known problems, how to apply BMPs, what studies actually pay off, etc.

BMP manuals to assist state DOTs in design of mitigation plans that are both technically feasible within their regions and acceptable to regulators are needed. As with the impacts themselves, BMPs that include structural, nonstructural, and bioengineered practices must be placed within the water watershed/ecosystem management context. The application of ecological restoration techniques as a means to mitigate impacts on a site-specific and watershed/ecosystem level should be reviewed as well. With respect to both BMPs and ecological restoration, reviews should consider cost-effectiveness with a sensitivity to future economic trends and developments.

Although not as pressing, research efforts also need to continue to focus on more accurately characterizing and quantifying transportation related runoff produced under varied conditions. For example, the current methodology assessing highway runoff often cannot accommodate requests and requirements of regulatory agencies and environmental reviewers. It is not sensitive to differences among proposed alternative alignments that are similar, nor is it sensitive to differences between alternative section types. And, while the current method can provide a

general impact assessment of newly constructed highway projects, it is not sensitive to highway widening projects. Pollutant loadings from transportation-related runoff need to be studied in greater detail. In particular, the contribution of deicing chemicals used on streets, highways, and airports must be investigated.

RESEARCH NEEDS STATEMENTS

Title: System to Facilitate Information Exchange

Problem Statement: Water-quality is an important and expensive concern for Federal, State and Local agencies, and organizations with a stake in highway planning, construction, and maintenance. Although many studies have been done to address water quality issues over the last 15-20 years, the information and data generated are often hard to find or impossible to obtain. Nationally, the costs for duplication of effort are a significant portion of the money spent on investigating and addressing water-quality problems. A readily accessible archive of information and key data sets including research results on the water-quality of highway-stormwater, best management practice (BMP) design and effectiveness, and related issues will provide necessary information and sources of data and expertise. The National Pollution Discharge Elimination System (NPDES) stormwater regulations cause highway departments to manage the sources and impacts of contamination from highway stormwater runoff. Therefore, water quality monitoring information and key data sets are being collected across the country by State DOTs, municipalities, and other public and private entities to comply with the NPDES and other regulations. Information on resulting beneficial use impairments of receiving waters would be of great value to researchers and all who must comply with regulations so that they may build on existing knowledge rather than repeating efforts when trying to protect water quality and beneficial uses. Currently, no effort is underway to assemble information and key data sets into a national database. A research vacuum exists. The NPDES program has led to a variety of BMPs for use in highway situations. Information available on BMP use, effectiveness, cost, and maintenance requirements would be a valuable characteristic of a national database.

A database accessible on, for example, the World Wide Web, would permit regional and national studies to be coordinated and would provide investigators with easy access to information outside their state or municipal boundaries. Information on stormwater management effectiveness and key data sets from monitoring efforts could be shared to reduce the costs. Development of a structure and a method to administer information and key data sets would facilitate discussion and research to improve data collection methods, interpretation techniques while unifying quality control measures, protocols, and formats for data collected. Currently there are no national formats established for information exchange on information and key data sets generated by the highway water-research community. Standard formats are required for documents, graphics and data that are portable.

Urgency: Improved information exchange is critical to save money on highway related water quality studies by facilitating more informed decisions, by keeping projects on schedule, and by eliminating duplication of effort.

Proposed Research: Develop and populate a computerized stormwater database to reduce the cost burden of complying with NPDES stormwater regulations, improve the cost/BMP effectiveness of non-point source pollution control, and to help address the issues of adverse impairments to receiving water. This objective can be met through a phased approach as follows:

Phase I. Feasibility Study ($100,000, 6 months). Poll selected participants including those on the NCHRP panel regarding needs for information and key data sets and the state of the data sources known to them. Design the structure of the database including how diverse information and key data sets are to be entered into the system. Generate a detailed Plan of Action to acquire national input concerning the information and key data sets, to enter it into the database, and to maintain the system as well keeping information and key data sets current once the system is established. The contractor will evaluate the most effective method of hosting the World Wide Web site. The contractor will evaluate the most effective method for user communications and for acceptance of information and key data sets from donors and will develop/adopt national formats for information exchange for reports, data, and graphics that are compatible with different computer platforms and software on different operating systems, and that do not require large computer storage resources. Phase I should also generate a standard shell and accompanying documents to facilitate creation of homepages by State Highway Administrations to further facilitate information transfer through a distributed system. The contractor will assess funding mechanisms to perpetuate the World Wide Web database beyond the conclusion of this project.

Phase II. Implement the Plan of Action ($350,000, 30 months). A. Develop software to include input of information and key data sets and management, and retrieval capabilities via the Internet (World Wide Web) (6 months). First, state DOTs are to be queried about the water-quality of highway-runoff information and key data sets that would be of greatest benefit to their environmental activities. The information and key data sets will then be evaluated for appropriateness and a list of information and key data sets to populate this database will be developed. Results of research, electronic copies of reports and graphics as well as the availability and formats of electronic data will be included. The project should also include the formation of specifications for different types of data to be added to the database through time. As a minimum, the database is to include highway runoff monitoring information and key data sets, BMP efficiencies, land use information upstream of monitored facilities, as well as their effectiveness, cost, maintenance, and space requirements. After the types of information and key data sets are finalized, information input, management and retrieval capabilities are to be developed. These capabilities are to include information input routines, query algorithms, and other information management capabilities. A prominent feature of the retrieval outputs will be a "disclaimer" to remove any liabilities of the system developers and those who input information into the system.

B. Assemble the information and key data sets from many different sources, including state DOTs, and enter the information and key data sets into the database (15 months; start 3 months after initiation of II.A). An extensive literature search is to be conducted as well as a detailed survey of state highway practitioners focusing on collecting the information and data in electronic format, if possible. After the information and key data sets are collected, they are to be evaluated and controlled for quality (adequacy, accuracy, and consistency). The information and key data sets which pass the quality control checks are to be entered into the database. A page with links to other relevant information sources including information currently provided by FHWA, EPA, USGS, TRB, NCHRP, CTE, and State Highway Agencies will be created.

Cost: $450,000
Duration: 36 months

Title: Method to Assess Effects of Highway Runoff on Aquatic Life and Receiving Waters

Problem Statement: Studies of highway and urban runoff have traditionally been driven by regulatory requirements relating to constituents and concentrations present in runoff. Indirect, delayed or synergistic effects are not fully studied and there remain uncertainties about the nature of short and long-term effects of highway runoff on surface and groundwater environments. Uncertainties can be costly because mitigation is typically required based upon TSS reductions rather than real impacts to local waters and ecosystems. While there are data about BMP effectiveness, the bulk of literature does not address standardized processes for removal, storage, fate, and impact of contaminants in the ecosystems. A practical operational method to evaluate and prioritize highway runoff and its affects on aquatic life needs to be examined in light of: (1) the physicochemical properties of the runoff and receiving water such as temperature, ionic strength, oxidation state, TSS, and pH- factors that determine the solubility and phase specificity, (2) the processes for entrainment, transport, and distribution of contaminants into ecosystems, or (3) the toxicological effect of highway contaminants in waters with different characteristics. Are any of these items likely to lead to an operational method to characterize impacts that highway practitioners can utilize without fear of controversy? Given a better understanding there is a need to develop decision protocols for effects based upon the local water quality, source, treatment, and ecology.

Urgency: The range of study costs and of alternative methods to deal with operationally predicting the effects of highway runoff upon aquatic receiving environments is extensive. Decision makers are often perplexed and many opt for high cost studies when more modest efforts would suffice. It is urgent to generate reasonable protocols to make studies of runoff effects.

Proposed Research: (A) Establish an operational methodology for the analysis of impacts resulting from highway runoff to stream fauna, as well as the downstream extent of these impacts, including aquatic invertebrate and fish species, and their population dynamics based upon the physicochemical properties, process oriented research, and accepted toxicological methods. (B) Identify the known short-term and long-term water quality effects of highway and transportation facility rnnoff on receiving water quality. These include chemical characteristics, flora and fauna population characteristics, species diversity, and toxicity (acute and chronic) in the tissues of key organisms in the respective ecosystems. Both surface water and groundwater and downstream surface water environments will be considered. The most wide-spread or detrimental characteristics of the highway runoff should be identified for field monitoring. (C) Conduct field monitoring at selected receiving water sites to fine tune impact protocols using modern analysis and field sampling methods. (D) Develop a prioritization method

to determine the probable significance of concentrations of pollutants in highway runoff that would affect receiving waters. This method would be used as a tool to direct efforts to mitigate water quality impacts using the most appropriate level of technology.

Cost: $450,000
Duration: 36 months

Title: Cost and Effectiveness of Stormwater Management Practices

Problem Statement: Federal, State and local regulations are driving the implementation of various best management practices (BMP's)--such as oil/grit separators, vegetated swales, detention ponds, infiltration trenches and basins, sand filters, and other technologies--to control stormwater runoff from highway drainage systems. To determine the overall cost effectiveness, each BMP needs to be evaluated in terms of short and long term costs, ability to sustain pollutant removal efficiencies, and long-term maintenance requirements.

Urgency: The need for a cost/benefit approach to define solutions that are economically and technically feasible and practicable for stormwater management is critical because regulatory requirements are growing more complex and more extensive while budgets for compliance are staying level, or are declining in real dollars.

Proposed Research: A project examining the cost and effectiveness of stormwater management practices will include development of a guidance document which presents specific cost/benefit data for each stormwater management option by evaluating:

- Typical cost factors associated with design, right-of-way purchase and construction;
- Pollutant removal efficiencies; and
- Routine maintenance procedures to maintain effectiveness such as regrading, revegetation, inlet/outlet renovation and sediment removal.

Cost: $300K
Duration: 18 months

Title: Guidance for Prioritizing Selection of Water Quality Impairment Mitigation Measures

Problem Statement: Highway agencies have limited resources for the construction and maintenance of mitigation facilities. It is imperative that the funds available for water quality pollution prevention be allocated to achieve the best cost benefit possible. Recognizing that there are specific highway uses and maintenance activities that have more significant impacts on receiving waters than others, there is a need for guidance that helps highway department officials weigh the mitigation options. This project will provide highway planners and designers with a sound scientific strategy for prioritizing selection of water quality impairment mitigation measures.

Urgency: Evaluation of the causes of environmental concerns emanating from highway construction and operations must deal with what is significant and what is not. Certain activities are clearly benign, others are not. A strategy to make early identification of critical concerns is needed to direct resources and to provide justification for lower priority to be assigned to items of negligible water quality and watershed impacts.

Proposed Research: The objective of this research is to develop a guidance document that:

- Provides a strategy for evaluating the relative impact of the highway land use and maintenance activity in a watershed, particularly with respect to any sensitive environmental resources;
- Identifies contaminants of concern;
- Provides a strategy for prioritizing the activities within the highway land use with respect to the larger picture of the watershed;
- Identifies the costs and benefits of the various methods for mitigation; and
- Identifies associated monitoring requirements for each mitigation option.

Cost: $200,000
Duration: 18 months

Title: Impacts of Air Emissions on Highway Runoff

Problem Statement: Highway agencies are required under NEPA and for NPDES permits to identify the impacts of highway runoff on receiving waters. One of the factors affecting water-quality pollutant loading is non-transportation related air emissions. Air emission "fallout" or deposition is not considered part of the background level of contamination, but instead becomes the treatment responsibility of highway agencies and, for local roads, municipalities. For example, an industry may emit significant quantities of particulate matter from its smokestacks, but the material falls on the highway or other impermeable surfaces that drain to the highway storm sewer system, these materials become part of the

highway water quality problem. Also, some air quality problems, such as acid deposition may exacerbate the highway pollutant runoff problem by lowering the pH of rainwater and causing a release of metals that previously were in an immobile form. Highway agencies recognize that vehicles are one source of contamination in highway runoff, but not the only source. Agencies need better scientific information on their relative responsibility so that they can negotiate equitable cost sharing agreements with municipalities for Best Management Practices.

Urgency: Under the Clean Water Act (CWA), all municipalities larger than 100,000 and the state highway storm sewer systems within these municipalities are subject to NPDES storm water permit regulations. Highway agencies may be spending far more than their fair share of costs for installing BMPs and need this data as a negotiating tool in cost sharing agreements.

Proposed Research: Using existing air and water quality data and models to the extent possible, determine the relative effects of atmospheric deposition and mobile source contributions to the quality of highway runoff in up to ten municipalities with populations greater than 100,000.

Cost: $150,000
Duration: 18 months

Title: Compost/Biosolids for Stormwater Runoff Management and Vegetation Enhancement and Associated Water Quality Impacts

Problem Statement: Recycling legislation has compelled transportation agencies to re-evaluate the disposal of right-of-way clearing operations and incorporate recycled materials into roadside development. The use of composted yard waste and biosolids will reduce the amount of organic waste being placed in landfills, burned, or otherwise disposed of.

Through a combination of filtration, biological, and hydraulic processes, compost/biosolids can be used as:

- stormwater runoff filtration devices to remove pollutants;
- erosion and sediment control measures; and
- soil amendments to foster vegetation establishment, in particular, vegetative filter strips and drainage swales.

Urgency: The need to dispose of biosolids and composted sludge is a significant public works problem. By the same token application of the materials immediately stabilizes soil areas subject to erosion and promotes rapid vegetation which provides longer term stability. The joint consideration of highway and public waste water ageucy needs stimulates this project. This process may provide a source of revenue stream to highway agencies from sewage authorities.

Proposed Research: Evaluate the cost benefits, constructability, and effectiveness of using compost and biosolids in highway applications for erosion and sediment control, filtering devices to enhance water quality and as a soil amendment for vegetation establishment.

There presently exist various mixtures of materials labeled as compost. This study will evaluate mature, stable compost and establish specifications for the material and its use in each of the following three outlined areas of study.

First, conduct a literature review and field studies to evaluate the relative success of using composted materials as an alternative erosion and sediment control device for *site stabilization*. Composted material should be evaluated against other standard erosion and sediment control devices for effectiveness in sediment removal.

Second, compile information from existing literature and field studies to investigate the effectiveness of using composted material as a filtration device in a hydraulic process such as a drop inlet or storm *drainage filtration* process. Evaluate the physical and chemical characteristics of the compost that enhance pollutant removal and determine its useful life cycle.

Third, conduct an investigation of using composted material as a *soil amendment*. This research should focus on compost material properties which would permit the reduction in the use of fertilizers and other chemical means in the establishment of vegetation.

The results of the study should provide a guidance document that describes the benefits, application areas, techniques, and methods of using compost and biosolids in a highway environment.

Cost: $400,000
Duration: 2 years

Title: Hydraulic Retrofits to Enhance Water Quality

Problem Statement: The highway community is faced with an emerging issue of water quality impacts. Existing infrastructure includes extensive hydraulic facilities which may be suitable for retrofit to provide water quality

benefits. Examples would be: 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 stormdrains. The project is oriented to these and other possibilities. State highway administrators are under lawsuit pressure to address water quality concerns. The NRDC third party CWA suit against CALTRANS is an example. Regulatory agencies as well as highway departments are targets. Reactive solutions can tend to be expensive and unwarranted even though they tend to relieve short term pressure. There are no coordinated programs to address how the existing infrastructure can be modified to benefit water quality. This is not a long term problem—it is critical right now. States are being reactive and spending money and do not have focused direction—efforts are scattered.

Urgency: The mitigation of 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.

Proposed Research: (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.

Cost: $250,000
Duration: 2 years

Title: Comprehensive Integrated Water Quality Management

Problem Statement: Many states are currently supporting projects that are assessing surface water quality, ground water quality, flooding, wetland protection, and streambank/shoreline erosion within a watershed/ecosystem framework. Transportation agencies need to respond to this trend by integrating their environmental planning, analysis, design, construction and maintenance into this framework.

One strategy to deal with highway runoff is to provide detention facilities to reduce peak runoff levels to predevelopment flood rates. Detention facilities include small impoundments that require land as part of a highway project. These facilities can be modified to have additional water quality benefits achievable with control device design. If the detention period is sufficient to hold a significant runoff event, such as the 25-year storm, the sediment load can be settled out. If further modified with small permanent pools, biotic activity can reduce uptake of dissolved contaminants. Extended detention and permanent pools can be combined to achieve significant water quality benefits, but there are very few criteria for designing and accounting for these benefits. Another strategy to deal with highway runoff is to provide grassed swales or created wetlands that also accomplish water quality benefits. A watershed approach that identifies a wide variety of BMPs, such as swales, wetlands and erosion control devices within the right-of-way may necessitate a review of geometric policies in the Green Book. Other watershed benefits of highway drainage features are related to conveying incidental spills and releases of fuel and oil. This dual usage implies that drainage design for runoff should also consider spill retention and temporary storage.

Urgency: The most current water quality research results of NCHRP, FHWA administrative contract, and staff research program efforts need to be integrated into a form that will ensure their usage throughout highway planning, design and operations activities.

Proposed Research: Determine how to integrate transportation environmental issues into a watershed planning framework. This involves integrating cross section, alignment, geometrics, and right-of-way design and planning with water quality protection in a watershed context. Develop planning guidelines and design details to accomplish multiple objectives for flow conveyance, peak flow attenuation, and water quality improvement. The guidelines need to address computation of predevelopment and post-development input hydrographs, the velocities of runoff into receiving waters, the appropriate risk levels in terms of return periods, and the volumes to be retained for extended periods as well as the volumes to be left in a permanent pool. Additional guidelines need to address maintenance and silt clean out strategy, spill contaminant, and inter-agency cooperation to utilize regional facilities that serve highway and non-highway runoff and possible wildlife use. It is unlikely that highway design will effectively respond to environmental pressures relating to water quality without this research. This research views the many aspects of design as a coordinated whole in order to address water quality improvement.

Cost: $300,000
Duration: 2 years

WETLANDS

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BACKGROUND PAPER

For transportation organizations, wetland issues are currently centered around the concept of cost-effective mitigation practices, with an emphasis on wetland banking and wetland construction methodologies, and the minimization of wetland impacts. In addition, the proposed new hydrogeomorphic wetland rating methodology represents additional challenges on wetland issues for transportation officials involved in evaluating and mitigating wetland impacts.

Mitigation efforts need to be examined in light of the evolving status of Prior Converted Wetlands. When dealing with Prior Converted Wetlands, one must be aware that "converted" is a reference to wetland area being converted to cropland. It does not mean the area was necessarily drained. The hydrological criterion for Prior Converted Wetland/Farmed Wetland is different from that for typical wetland delineation and is related to having an extended inundation period and not merely saturation. The use of Prior Converted Wetlands as mitigation sites probably offers the least expensive form of mitigation. Another form of low-cost mitigation is associated with transforming borrow operations into mitigation sites. These cost-effective techniques need to be fully examined and documented.

Another cost-effective wetland mitigation opportunity involves the construction of stormwater detention basins and other non-point source pollution control measures for water quality treatment and enhancement. Currently, these measures do not count towards fulfilling wetland compensation requirements. When these basins are of sufficient size, they frequently support a diverse wetland resource. The value of these systems should be documented and the results used in negotiations with regulatory and resource agencies who need to support transfer of environmental credits into the regulatory forum.

Wetland evaluation is not a high research priority for transportation because the new U.S. Army Corps of Engineers *Hydrogeomorphic Approach to Wetland Assessment and Evaluation* is now under active development, but to our knowledge, this assessment methodology has not been tested by a transportation organization via a permit application. The time required to conduct the wetland assessments for long-linear projects is unknown and not all the required models for the different types of wetlands have been developed. Transportation organizations will likely be among the first users of this methodology. Research efforts directed at pilot projects applying this method to transportation projects should be considered. In this vein, there needs to be a nationwide reevaluation of the ecological value of regulating highway drainage ditches. In some regions of the country, these ditch networks are not regulated under the 404 Program and in other regions they are regulated. Where regulated, these ditches are often treated as requiring full mitigation efforts, even though they are likely to be replaced in widening programs.

Wetland mitigation banking is still in its infancy. The Corps has issued guidelines for the development of banks, but key issues have not been resolved (*Wetland Mitigation Banking: National Wetland Mitigation Banking Study*, IWR REPORT 94-WMB-6, Institute of Water Resources, Water Resources Support Center, Alexandria, Virginia). Of particular concern to transportation organizations is creation and easy use of banks. Regulatory focus on in-kind mitigation and especially in-watershed mitigation can make the development of an efficient network of banks in any state difficult. In coastal states, numerous different small watersheds discharge directly into marine

environments without becoming part of a major drainage basin. It is unclear whether a bank in each of these small watersheds would be required. It must be recognized that defining the geographic limits that the individual banks serve may be a real problem and guidelines will need to be developed that emphasize practical solutions. Resolving credit ratios for restoration and enhancement efforts need both documentation and study. Clearly, preservation credits can be part of a total mitigation package, even in light of the no-net-loss policy, but it may be difficult to convince regulatory agencies because those resources are thought to be protected under the current 404 Program. This needs to be explored further since there may be many specific circumstances where preservation of existing wetlands and buffer areas can present valuable ecological benefit.

Bank development is problematic when the regulatory community does not fully embrace the concept. Where transportation organizations have developed an efficient banking network, technical documents should be prepared outlining how the bank works, how in-watershed and proximity issues were handled, and how other tough issues and negotiations were resolved with the regulatory agencies. Fee-based compensatory mitigation where the permittee pays a fee to another resource agency, such as state Fish & Wildlife, to construct the mitigation, is likely to be a very attractive alternative to most transportation organizations. This form of mitigation needs to be identified and documented. Also, the development of watershed-based wetland management and opportunities to incorporate wetland banking and other forms of mitigation is an opportunity that needs to be fully explored by transportation agencies.

Banks will not be a panacea for unavoidable impacts because on-site mitigation will likely be viewed as preferable to off-site, even where banks exist. As such, highway organizations will still frequently engage in wetland creation activities. By comparing on-site mitigation costs with banking efforts, we should be able to quantify cost savings associated with banking, but such a comparison may be premature until more bank sites are developed. Currently, the U.S. Army Corps of Engineers is preparing a multi-volume *Wetland Engineering Handbook*. This handbook is an overview of the engineering practices required for successful wetland mitigation. This series includes a volume of guideline engineering specifications for wetland plant establishment and sub-grade preparation. These specifications are written in a five part format typical of many transportation organizations. The vegetation specifications focus on freshwater and salt marsh establishment, reforestation practices, and various seeding programs. It is weakest in western riparian mitigation practices. A similar volume is currently being prepared by the FHWA - *Guidelines for the Development of Wetland Replacement Areas* (National Cooperative Research Program, Report 25-3, Transportation Research Board, National Research Council, Washington, D.C.). This latter volume has a similar focus, but the volumes are not overlapping. As an overall theme, research efforts are needed to evaluate the cost-effectiveness of past mitigation practices, including banking to provide a solid base for future decision making.

In summary the focus of new research efforts is likely to be cost-effective wetland mitigation practices, including banking, application of emergent wetland evaluation techniques to transportation projects and development of rational choices for mitigation that embrace watershed resource planning. These efforts should not be allowed to overshadow the importance of a review of minimization practices. The need to develop national approaches to many wetland-highway issues is evident, but such efforts must have regulatory affirmation or they will be virtually worthless. The results of well-targeted research will provide needed empirical support for building consensus for new agreements among stakeholders.

RESEARCH NEEDS STATEMENTS

Title: Evaluation of Preservation and Fee-Based Compensation as Methods for Department of Transportation (DOT) Compensatory Mitigation

Problem Statement: Typically, regulatory agencies require restoration and/or creation of wetlands as compensatory mitigation for unavoidable wetland impacts. This type of mitigation typically requires the DOT to be closely involved in the development or restoration of compensation sites including land purchase, mitigation design, construction, and monitoring of replacement wetlands and long-term maintenance. This type of involvement is typically costly, requires significant amount of staff involvement and long-term maintenance and ownership responsibilities. Frequently, DOTs may not have the long-term resources, staff, or expertise to carry out these responsibilities.

DOTs often have project funds available to pay for wetland mitigation but are often limited in the long-term availability of staff and/or funds for on-going maintenance and land ownership. As a result, purchase and preservation as well as fee-based compensatory mitigation are

attractive options for DOTs needing to mitigate for wetland impacts. However, the federal, state and local "No Net Loss" policies should be factored into the applicability of these compensation methods.

Alternatives to wetland creation and restoration can involve preserving existing wetlands or fee-based compensatory mitigation. For the purposes of this research, preservation includes purchase and transfer of property title to a resource agency or maintenance organization and fee-based mitigation is defined as the DOT paying into an established fund or buying credits from an established mitigation bank or similar circumstance.

Proposed Research: Collect information on projects conducted by state, federal, local, and private entities where preservation or fee-based compensatory mitigation was used.

Compile collected information into case studies. Develop a database to compare and review data. List project conditions that make preservation and/or various fee-based mitigation scenarios acceptable to the regulatory agencies. Develop technical guidelines and administrative requirements for implementing preservation and fee-based mitigation programs.

Specific tasks that should be conducted as part of this research are outlined below:

Data Collection: (including, but not limited to) 1) mitigation alternatives considered, 2) reasons for using fee-based compensation or preservation rather than applicant established wetland creation or restoration, 3) agencies and organizations involved in the process, 4) process documentation developed (i.e., MOUs, etc.), 5) date when mitigation established (if any), 6) date impact occurred, 7) ecological effects of mitigation, 8) effectiveness of preservation or fee-based mitigation in replacing affected wetland functions, 9) problems encountered, and 10) cost per acre.

Evaluation of collected data: (including, but not limited to) 1) compile case studies, 2) determine conditions where preservation or fee-based compensation was or could be acceptable for use, 3) develop list of problems encountered, 4) recommend agencies and organizations that should be involved, 5) develop technical guidelines for when preservation and fee-based compensation might be acceptable, and (6) explore additional opportunities for alternative compensatory mitigation for DOTs.

Cost: $200,000
Duration: 18 months

Title: Evaluation of Techniques for Improving the Ecological Success and Increasing the Cost-Benefit of Mitigation

Problem Statement: Annually, millions of dollars are expended on the planning, design and construction of wetlands mitigation projects. Many projects involve particular construction techniques that are expensive and of questionable ecological value. For example, wetlands creation projects typically involve significant earthwork which drives up project costs yet with limited ecological success. Similarly, efforts to restore or create forested wetland systems often involve expensive planting. The success of these planting operations can vary. Alternatively, volunteer revegetation may, under certain circumstances, be more effective than planting at mitigation sites. For transportation projects impacting small areas of wetlands (less than one acre), the total cost per acre of restoring or creating small areas might be extremely high. Moreover, for certain regional wetland types, there is limited technical knowledge on how to successfully recreate, restore or enhance these wetland systems. Finally, there is limited information on the general costs of mitigation that limits the ability to conduct cost-benefit analyses. There is a need for a thorough survey of the cost-effectiveness of current wetland replacement techniques.

Proposed Research: Building upon existing information, evaluate and compare techniques/methods for creating, restoring and enhancing wetlands currently being used by transportation agencies. Emphasis should be placed on evaluating the effectiveness of alternative techniques (e.g., volunteer revegetation vs. planting) that have the potential to reduce project costs and improve the ecological success of similar restoration or enhancement efforts. Research efforts should also focus on identifying techniques for restoring or enhancing wetland types and complexes where there is limited existing information. Wetland restoration and creation costs for different wetland types in different regions of the country should be broken down by topics including, but not limited to, site identification and acquisition, project size, planning and design, construction practices (e.g., planting, earthwork), monitoring and retrofitting. Techniques and methods should be evaluated in terms of costs, effectiveness and practicality. Study results will identify cost-effective and ecologically-desirable wetland restoration or enhancement techniques for transportation agencies.

Cost: $200,000.
Duration: 24 months

Title: Pilot Projects to Apply Hydrogeomorphic (HGM) Wetland Assessment Methods to Highway Projects

Problem Statement: Wetland regulatory agencies might soon require that impacts to wetlands under the 404 permit process be assessed using the hydrogeomorphic (HGM) approach. This approach assesses the differences in functional capacity between impacted and unimpacted, "reference" wetlands of the same kind. Natural variations between sites are distinguished from man-induced variation by first classifying wetlands according to HGM-class and then evaluating differences within that class based on field data from reference sites. This requires that reference sites encompass both altered and unaltered sites. Information on the least altered sites provides reference standards by which functions of wetlands of that same class can be measured. It also provides quantifiable goals by which to judge the success of restoring or managing ecological conditions of landscapes.

The development of HGM functional models and the applications framework for the 404 process is an ongoing effort under management and direction of the Corps of Engineers. This proposal addresses the need for a pilot project to apply the HGM assessment procedure to highway projects, both the NEPA impact assessment process and the 404 compliance process (including the design and implementation of compensatory mitigation).

Proposed Research: 1. Identify priority wetland types impacted by highway projects. Priority would be determined by frequency and severity of impact on wetlands, effects of compliance process on project scheduling, and regulatory agency acceptance of compensatory mitigation initiatives. The wetland types identified should be classified by HGM class and Cowardin classifications.

2. Identify HGM functional models which have been completed at least through a draft or operational draft phase. Apply one to three of these models to highway projects, including impact assessment under NEPA, compliance with E. O. 11990, CWA, Section 404 permit regulatory process, applicable state regulations, and development of appropriate mitigation. The mitigation process should include feasibility analysis of compensatory alternatives of creation; enhancement, restoration, and preservation; determination of compensatory ratio; mitigation site selection; and mitigation project site design.

3. Evaluate the applicability of the HGM assessment procedure to highway projects, including recommendations for additional procedures, policies, or technology.

4. Develop technical guidance for the application of HGM assessment procedures to highway projects in general.

Cost: $50,000 - $150,000
Duration: 2 years

Title: Evalnation of Constructed DOT Wetland Mitigation Projects--Recommendations For Future Actions.

Problem Statement: Over the past two decades, transportation agencies have been required to mitigate wetland impacts of projects. Mitigation activities have included functional replacement, restoration/enhancement and preservation. The requirement to mitigate has been through issuance of specific conditions to wetland permits, which include monitoring and specific performance specifications that describe the success of mitigation. A key concern by the regulatory and resource management agencies has always beeu to replace lost wetland functions in kind. Some mitigation designs attempt to address this as a goal, often at great effort and considerable expense. Although considerable information exists on the total inventory of mitigation projects nationwide, a current synthesis identifying the results achieved by DOT projects is needed. Given the vast amount of effort and resources expended, the absence of this information leads to the inability to evaluate the accrued public benefit or to establish benchmarks for policy makers to use in decisions for future mitigation actions. Successful mitigation has two components, regulatory compliance- did the project meet the permit monitoring performance criteria (percent cover, etc.); and functional compliance- did the project meet the design criteria for functional replacement and did the project result in ecologically valuable wetlands.

The answers to these questions can lead to the reevaluation of policies by regulators, resource agencies and the regulated community regarding the level of precision required for in-kind functional replacement. Therefore, the research objective is to establish the results of past mitigation projects and provide technical guidance for the direction of future mitigation efforts.

Proposed Research: The study will need to incorporate a series of elements to determine success. The first element is to establish the success criteria. This must consider any goals or performance standards that may have been established in the permit/project documentation. The second element is to compare the post-construction project to preconstruction design. The third element is to assess the level of ecological function irrespective of the initial goals

or design. The work should include review of mitigation project files from selected state DOTs to obtain a geographically representative data base for the Nation. When adequate documentation is available (i.e., preconstruction goals and performance standards, pre- and post-construction plans and monitoring reports exist), assessment may be made based on a desk audit. Absent complete documentation, a field assessment will be necessary. In the scenario where no goals were established prior to construction, then success must be evaluated in a more abstract manner. In such cases an evaluation of standard ecological parameters (e.g., diversity of cover type, and assessment of ecological functions) and qualitative comparison to reference conditions of similar habitat/hydrologic regimes can be used to assign ecological success. The results of the survey will be evaluated and recommendations made on setting realistic goals for future functional replacement. Technical guidance should be provided on whether certain types of efforts (e.g., in-kind, on-site) are more, or less effective than others (e.g., mitigation banks); levels of planning and design necessary to insure success; and whether success can be predicted based on wetland type, hydrologic regime or other variables.

Cost: $350,000
Duration: 18 months

Title: Opportunities for DOT Participation in Watershed Based Planning for Wetlands Management

Problem Statement: Linear transportation systems (rail, road, air and water) cross and interconnect most watersheds in the US. Mitigation is typically done on a case-by-case basis, with priorities driven by each project's schedule and the regulatory process. This approach fosters a piecemeal approach to mitigation, ignoring the top priorities and needs of individual watersheds. Federal, state, and local agencies are promoting watershed planning, and there is a role in this process for DOT agencies, which can have major direct and indirect impacts on watersheds.

Methods are not available for regulatory compliance or wetland mitigation to occur on a watershed or ecosystem scale basis. Cost-effective mitigation alternatives, such as off-site, out-of-kind or wetland banking are potentially useful tools for transportation agencies, but, must fit into an overall watershed comprehensive planning process for acceptance. Developing this planning process is the purpose of this research.

Proposed Research: Develop a methodology or technology to allow the understanding of the entire watershed function, and identify present and future activities that could affect it, including transportation systems. Means to do this should be direct, simple and cost-effective. Useful methodology used in past and current studies on integrated land use plans and models, watershed study case histories, and special area management plans should be evaluated and utilized if possible in this study. This method should measure and inventory the watershed resources, conditions, health, values and impacts. Direct and indirect impacts, as well as cumulative impacts, due to transportation projects, must be able to be included in the study. A process for assessing and prioritizing immediate and long term deficiencies and needs for watershed restoration must be identified, leading to an agreed upon comprehensive mitigation plan. Watershed needs relating to fish and wildlife, wetlands, stormwater or flooding needs or retrofits should be included.

Watershed plans should integrate regulatory as well as non-regulatory approaches for wetlands management toward the goal of whole watershed management. Watershed plans for wetland restoration and management should involve process elements, such as stakeholder and public participation, and technical elements, including a method for consolidation of a variety of technical information, such as wetlands mapping and functional assessment and identification of restoration opportunities from a variety of sources. Implementation elements, which need to reflect a management-oriented vision for the watershed, should involve a wetland categorization scheme that determines which wetland areas in the watershed will be open to new development (subject to mitigation requirements), which watershed areas will be closed to new development, and which areas will be used for wetland restoration through regulatory mitigation and non-regulatory efforts.

A decision-making framework must be developed to provide a foundation for developing ongoing communications and partnerships between watershed stakeholders and regulatory agencies and the transportation project and mitigation planning process.

Identify and evaluate the implications of such a watershed plan for highway planning and regulatory compliance, and specify what resources DOT agencies can bring to the process, how they participate in the process, and how transportation planning is incorporated into the process.

The information about a watershed that will be obtained by following the procedures and methodology developed by this study will be highly valued by regulators, stakeholders and the development community. The financial responsibilities of conducting this study must extend beyond the transportation agency involved. Recommenda-

tions as to funding options and opportunities must be developed as part of this study.

Products expected from this research include: a model methodology that would apply in any given watershed for describing watershed resources, deficiencies and potential impacts; a decision-making framework for stakeholder coordination and regulatory compliance, identification in detail how DOT agencies will be involved in and contribute to the process; and finally, recommended funding partners for conducting the study.

Cost: $250,000
Duration: 18 months

WILDLIFE & ECOSYSTEMS

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BACKGROUND PAPER

Impacts of transportation projects on wildlife and ecosystems are of major concern to natural resource trustees, state and federal departments of transportation, and private citizens. Wildlife and ecosystem impacts are currently centered on the concept of mitigating ecosystem fragmentation and disruption, and collision avoidance. Over the past five years, few research programs have actually been initiated to investigate the impacts of transportation projects on wildlife and ecosystems. In fact, many of the suggested research needs for this year are the same or similar to those received previously, reflecting that there are some important wildlife and ecosystems concerns that still need to be addressed.

Fish and wildlife populations and communities are constantly changing through births, deaths, immigration, and emigration. Underlying this change, however, is a certain range of possibilities that help to define a given community. In the absence of additional outside influences, species composition and relative abundance in a community can be expected to vary within definable boundaries. Habitat disruption or fragmentation can bring about changes in the numbers of births and deaths resulting in reductions in population size. Fish and wildlife populations may also be reduced through increased emigration or decreased immigration in response to changes in habitat structure. Habitat fragmentation and disruption, which causes changes in the size of particular populations, could also result in the secondary effect of changing the composition and structure of fish and wildlife communities and ecosystems. As transportation projects induce modifications in species composition and relative abundance of populations in a community, the often complex pattern of energy flow within the ecosystem can change. If certain key species are reduced or eliminated the community may support fewer species and become an ecosystem of lower value. Additional data are necessary on how both re-developed and new transportation projects bring about habitat changes that result in changes in biodiversity.

Other concerns surround the utilization of transportation corridors by wildlife. Information on the actual utilization of medians, loops etc. by animals needs to be examined versus the adjacent areas of transportation corridors in order to examine whether or not the size of medians or loops, the naturalizing of medians and shoulders, and plantings of potentially palatable vegetation are significantly contributing to potential wildlife and ecosystem impacts. Similarly, case studies on the actual usage of wildlife overpasses, tunnels, etc. that have been constructed would also be appropriate. Further data needs to be collected to determine if DOTs' actions in attempting to reduce maintenance costs by using wildflower plantings and certain trees and shrubs, or constructing nesting boxes, etc. near highways without appropriately assessing the impacts are only adding to the increased usage of the transportation corridors by wildlife, thereby compounding the ecosystem impacts of transportation facilities.

Additional research efforts are needed on the impact that transportation projects have on the accumulation of contaminants in community and ecosystem food chains. Whether this contaminant loading originates from point or non-point sources, the present information cannot accommodate the increasing demand for this data. Research needs to be undertaken not only for the potential air pollution impacts but also for road runoff and should include chemical and physical stressors (i.e., road sand). Little information is available to properly assess the long-

term or short-term impacts of roadside contamination at the ecosystem level. Although the majority of the chemicals of concern include polycyclic aromatic hydrocarbons, nitrogen-containing organics, and some metals, few models exist to properly evaluate their impacts on wildlife species through ingestion and inhalation of these contaminants. Further research is necessary to assist in standardizing uptake and exposure levels for different ecological receptors in different environments. Few criteria or toxicity data exist for both single compounds or complex mixtures to evaluate potential impacts to wildlife and ecosystems. There are no widely accepted criteria for evaluating the significance of roadside soil, air, and vegetation contamination. Additional research in these areas is a critical need to better evaluate these potential impacts from transportation projects.

Currently there are limitations in available policy and guidance that articulate the extent to which ecological data should be collected and used when considering wildlife and ecosystem impacts. The absence of policy and guidance in many cases is due to the lack of appropriate scientific knowledge and data, and additional fundamental research addressing these data gaps is clearly needed. Although the difficulty of developing such policy and guidance in the face of existing scientific uncertainties is widely recognized, some policy decisions could be reached given the current knowledge and data. For example, one of the most fundamental impact management issues is the selection of appropriate biotic receptors and ecological effects to evaluate. There is a virtually infinite number of combinations of receptors and effects that can be considered for a transportation project, however, there is no general consensus on what priority should be given to which receptors and which endpoints in terms of evaluating and minimizing effects. In addition specific guidance needs to be developed to aid in the determination of when an ecological threat is significant and thus worthy of mitigation. A compilation of information on critical parameters of physiology, metabolism, and natural history would facilitate quantitative estimates of potential impact. The lack of sufficient policy and guidance also may result in inadequate ecological management decisions in the sense that opportunities for ecological protection or enhancement may be lost or that ecologically detrimental alternatives may be implemented.

Transportation agencies regularly construct stormwater detention basins or direct outfalls for stormwater management as part of the required mitigation efforts associated with transportation projects. Currently, however, these measures have not been appropriately examined as to the potential indirect impacts of erosion on the ecosystems in the receiving water bodies. The introduction of significant water volumes and high input velocities can cause significant impacts to the ecosystem for large reaches down stream. Recently, mitigation of these impacts has been attempted through stream restorations (i.e., rechannelizations) to help accommodate the increased water volume and velocity. The overall effectiveness of this habitat improvement/mitigation action has not been adequately evaluated. The implementation of this mitigation measure is still too new and little follow-up monitoring has been performed for the mitigation effort to be judged as being successful. Additional research is needed to adequately determine the effectiveness of this mitigation measure and to explore additional alternatives where necessary.

Environmental assessment techniques in transportation projects are usually limited to existing methodology and guidelines. Development of new assessment procedures and guidelines is generally outside the realm of transportation environmental impact assessments. However, research to develop new assessment techniques and guidelines for a variety of transportation-related impacts to wildlife and ecosystem is needed including: evaluating noise impacts on sensitive species; evaluating use of culverts vs. bridges; assessing the impacts associated with relocations of populations; nationwide standardization of assessment techniques; guidelines for in-kind versus out-of-kind mitigation; and developing criteria for when to implement collision avoidance measures. In addition, characterization of impact would be made more accurate, consistent and comprehensive by delineating a standard set of organisms and endpoints for evaluating threats to particular ecosystems. The purpose of developing these new assessment procedures and guidelines is to not only improve the quality and predictability of ecosystem impact assessments, but also to improve the explanation of investigation impacts, mitigation and conclusions to all interested parties.

RESEARCH NEEDS STATEMENTS

Title: Identification of Upland Ecological Functions Which are Appropriate for Assessing the Impacts of Transportation Projects on Ecosystems

Problem Statement: Based on experience with assessment of wetlands, it has been useful to express the integrity, condition, or state of wetlands in terms of functions. The advantages of using functions in ecosystem assessment are that functions (1) are more robust in depicting an ecosystem condition better than a single index of integrity, (2) provide the detail that is often necessary for establishing mitigation goals, and (3) relate to specific societal values that facilitate environmental review processes. Considerable ecological research has been conducted on upland ecosystems throughout the country. Typical examples of important functions are maintaining characteristic levels of primary productivity, site water balance, elemental cycling, food webs, vertebrate populations, etc. However, there has been little attempt to employ the measurement of functions as an assessment tool for ecological integrity in upland ecosystems. The project will identify ecological functions of uplands that are appropriate to assessing the impacts to ecosystems by transportation projects.

Proposed Research: Conduct a workshop to establish functions for upland ecosystems that can be practically applied to impact assessment by transportation projects. The workshop would serve to provide a strong scientific foundation for the assessment of upland ecosystems. The major product of the workshop would be synthesis papers that document the presence of relevant functions in the general areas of hydrology, biogeochemistry, food web and habitat support, landscape-scale functions, and others, as appropriate. Papers chosen from major biomes of the United States would provide a geographic distribution applicable to a number of DOTs. The Long Term Ecological Research Program of NSF has projects distributed across major biomes (boreal forest, Pacific Northwest coniferous forest, shortgrass prairie, temperate deciduous forest, etc.) and the research infrastructure to facilitate the development of synthesis papers. Participation by agency facilitators would be needed to ensure useful end products for interfacing with related efforts to develop standards for upland ecosystems. Spatial scales at which identified functions occur must be made explicit.

Cost: $70,000
Duration: 2 Years

Title: Establishing the Relationship Between Roadway Density and Ecosystem Integrity

Problem Statement: Construction of new roadway corridors or expansion of existing roadways (increases in road intensity) may increase habitat fragmentation and have an adverse effect upon wildlife populations and the overall health or integrity of ecosystems. There is an absence of data concerning impacts of additional fragmentation of an already fragmented landscape and whether this has any substantive effect upon ecosystem integrity. Extensive biological surveys to determine the potential biodiversity effects of individual road projects are time-consuming, costly, subject to dispute over interpretation of results, and have limited application beyond the specific project studied. A rapid assessment methodology is needed to aid transportation and regulatory agencies in determining whether or not projects are likely to exceed the habitat fragmentation thresholds of given landscapes.

Studies have shown that road densities above a certain threshold are correlated with reduced populations of certain vertebrates. Road density has also been proposed as a broad index of the ecological effects of roads within a landscape unit. Therefore, changes in road density or intensity may be an easy and useful indicator by which to measure potential impacts to ecosystems specifically related to wildlife populations.

Proposed Research: 1) Produce an annotated bibliography and synthesis of existing research on the relationship of roadway density and intensity and: ecosystem integrity or health, and wildlife diversity and density.

2) Establish the appropriate size of landscape units in which to measure roadway density/intensity.

3) Develop methodologies to determine thresholds of roadway density/intensity.

4) Correlate highway densities in large landscapes (from GIS based data sets) with known species-specific population sizes for landscapes of similar type to identify threshold levels of road density and intensity (usage) including the relationship of lane km/sq. km, AADT, and other appropriate transportation facility characteristics.

5) Develop guidance thresholds (in habitat types of selected ecoregions) for levels of roadway density/intensity that adversely affect ecosystem integrity.

Cost: $750,000

Duration: 2 Years

Title: Ecosystem-based Transportation Corridor Assessment

Problem Statement: Transportation project construction and operation often alters ecosystem structure and function by reducing population sizes of plant and animal species and disturbing natural communities. While this problem has been adequately studied and identified, widely applicable solutions have not. Mitigation is most often based on individual projects or micro solutions, however, for ecosystems and wide-ranging species, macro solutions are needed, but the information necessary to formulate such solutions is not always available. Most mitigation projects are done independently, although coordinated action may offer greater effectiveness at much reduced costs.

Proposed Research: Join in selected pilot efforts at ecoregional planning to:

1) Identify ecosystems, species, and natural communities that are particularly vulnerable;
2) Identify the sources of these threats;
3) Propose strategies and plans to protect or mitigate those ecosystems, species, and natural communities at risk; and
4) Identify partners to participate in plan development and strategy implementation.

For example, The Nature Conservancy is launching an effort to develop comprehensive conservation plans on an ecoregional basis throughout the United States. The Conservancy has identified 57 ecoregional planning units for this initiative. The TRB could join in selected pilot projects to explore ways in which ecoregional planning could assist the transportation sector in fulfilling its mission while meeting existing environmental requirements, as well as the emerging move towards ecosystem management.

Example of one of these ecoregional planning efforts: Northern Great Plains Steppe ecoregion. This pilot area encompasses portions of Montana, Wyoming, North Dakota, South Dakota, Nebraska in the United States and Alberta and Saskatchewan in Canada. The core planning team consists of ecologists, botanists, zoologists, GIS experts, and planners from The Nature Conservancy, the Natural Heritage Network, and other agencies. Participation in this and similar pilot projects would help assess the utility of conducting similar, or modified, transportation-related, biodiversity threat, and solution analyses in other regions of the United States.

Cost: **$600,000** ($75,000/pilot project/year)
Duration: 2 Years

Title: Evaluation of Published Case Studies and Representative Completed Projects to Determine Effectiveness of Corridor Connections to Reduce Fragmentation by Transportation Facilities

Problem Statement: Although much remains to be known on how and to what degree transportation systems reduce ecosystem functions, measures have been undertaken by several transportation agencies to reduce fragmentation of ecosystems due to transportatiou facilities. Collectively these various mitigation measures define the ever-evolving technology for reducing ecosystem fragmentation. Some transportation agencies have attempted to use highway corridors and greenways/pathways as a means to provide connectivity between fragmented ecosystems. Several transportation agencies have utilized wildlife passageways, such as bridge extensions, overpasses, underpasses, culverts, and vegetated strips as a means to connect habitat fragments caused by construction. The efficacy of these efforts remains generally unstudied.

Proposed Research: The study will identify measures developed to connect habitat fragments due to transportation facilities and survey case studies by transportation agencies. These identified measures should be evaluated to determine what results were achieved, at what cost, and indirect benefits or liabilities.

Field investigations should be undertaken for a representative set of passageways developed/constructed specifically for connecting habitat fragments. Data should be collected on the utilization of these facilities by an array of select indicator species including those species for which the project was developed. Appropriate controls should be used.

Cost: $350,000
Duration: 3 years

Title: Synthesis of Transportation Agency Ecosystem/Mitigation Experience

Problem Statement: Transportation agencies at the local, state, national, and international levels are assessing ecosystem impacts, implementing mitigation measures, and developing management plans for their programs and project implementation. Information regarding these

activities is currently available only through the individual agencies. Since the information would be of great benefit to other transportation agencies that may be facing similar situations, it should be gathered into a single location so that others can gain easy access. With information on the experience of others, failures need not be duplicated but successes can be repeated. Even where failures occurred, corrective action can be taken to improve chances of success at other locations.

Proposed Research: This research project would contact transportation agencies and identify programs and projects that have addressed vegetation and wildlife issues including:

- Fragmentation/connectivity;
- Wildlife habitat replacement, enhancement, and preservation;
- Operation and ecosystem management practices;
- Interagency agreements aimed at improving ecosystems;
- Funding of ecosystem restoration;
- The effectiveness of design features in the reduction of wildlife mortality;
- Migration and control of invasive species; and
- Uses of existing biological data (such as natural heritage data) to evaluate and plan transportation projects.

Once identified, each program or project should be described in detail including methodology used to establish impact, basis for plan, goal of activity, agencies or other entities involved, design considerations, operation and maintenance considerations, action taken, acceptance among stakeholders, perceived success, and any analysis conducted to measure success. It is also of interest whether the action taken was a result of a negotiated settlement or through scientific analysis.

The opinion of the transportation agency is also important regarding whether it would repeat the exercise and whether it was cost effective. Any other comments from the implementing agency would also be welcomed and encouraged.

A synthesis report will be prepared.

Cost: $150,000
Duration: 18 months

Title: Develop Standards for Characterizing the Integrity of Upland Ecosystems

Approaches for the assessment of aquatic and wetland ecosystems have adopted the concept of reference ecosystems as benchmarks for detecting ecosystem change from impacts by human activities. For aquatic ecosystems, indices of biotic integrity (IBI) have been developed, and for wetland ecosystems, the hydrogeomorphic approach (HGM) is under development. In order to apply the concept of reference to ecosystems, standards must be developed to reflect least altered conditions (i.e., minimally impaired, highest sustainable functions, biological integrity, historical conditions, and so forth). These concepts of reference condition have not been explicitly applied in the assessment of impacts to upland ecosystems (in contrast to aquatic and wetland ecosystems). The proposed research projects outlined below explicitly invoke the concept of reference ecosystems to uplands in the assessment of environmental impacts of transportation projects. By building upon the experience gained in IBI and HGM assessment approaches, application to upland ecosystems can advance relatively quickly.

To apply functional assessment to uplands, standards must be established that characterize ecosystems at their highest level of sustainable functioning. Such indicators or variables that are used for standards must be easily observed in the field to be practical for use in impact assessment and mitigation efforts.

Problem Statement: There are two interrelated phases to this project, the development of field methods and techniques, and the determination of indicators and variables that are practical to collect and that will be useful in characterizing functions.

Development of field methods and analysis techniques:
A vast array of field methods and data analysis techniques are available for studies of ecosystems. Many are impractical for the assessment of the impacts of transportation projects on ecosystems because of cost and time requirements. The most appropriate methods are (a) relatively inexpensive, (b) easily implemented by field biologists, (c) rigorous enough to meet NEPA requirements and those of state and local agencies, and (d) can be consistently applied to a variety of ecosystems. Adaptation of existing methods and the development of new techniques would contribute to consistency and efficiency for both field and data analysis components. Methods developed in forest assessment, wildlife population censuses, rangeland management, natural resource inventories, and related techniques usually can be adapted with little modification to meet the requirements of ecosystem assessment.

Develop indicators and variables:
Standards developed for a particular class of upland ecosystems are reflective of the highest levels of functioning sustained by sites with the least alteration. Functions can be modeled as aggregates of indicators and variables that bear known or hypothesized relationships to the function. Indicators should be chosen based on sensitivity to anthropogenic impacts and variables should be useful not only in evaluating changes in function, but also in developing designs for restoration. For example, measurable habitat features of an ecosystem may correspond to potential population densities of a given species. For example, successful nesting sites for certain bird species may depend on mature forest structure, appropriate feeding habitat, and the absence of brood parasites. Indicators or variables contributing to these conditions may include a mixture of deciduous tree species of a given size-class distribution age and a location more than several hundred meters distance from a highly altered site.

Indicators and variables of functions may have similarities among ecosystems classes, but the specifics will change based on species composition, landscape position, vegetation structure, soil properties, detrital mass, ground cover, and so forth. Standards based on reference condition must be determined for each ecosystem class. Once these standards are developed, assessment of ecosystem functions will involve the comparison of indicators and variables of the site being assessed with the standards for the class.

These standards should be developed for several ecosystem classes to illustrate their application to functional assessment. They can serve as templates for the development of standards for other priority ecosystem classes.

Proposed Research: *Development of field methods and analysis techniques* - Methods will be adapted and developed to assess the functioning of ecosystems relative to standards developed for unaltered ecosystems. Because of the need to apply different techniques among ecosystem classes, four structurally distinct ecosystems will be chosen for testing and refining methods: warm temperate deciduous forest, shortgrass prairie, warm desert, and evergreen coniferous forest. Products of this research will include published papers and manuals. The manuals should be in a format useful for the technical training of practitioners of ecosystem assessment. Recommendations and examples will be provided on how to analyze data and how to compare the results to standards of reference ecosystems.

Cost: $300,000 ($75,000 each for 4 projects)
Duration: 2 years

Develop indicators and variables - Standards will be developed for four ecosystem classes (the same ones for which methods were discussed). The indicators and variables that support these standards will be tested by applying them to altered ecosystems that have lower levels of functioning, based on the judgment of knowledgeable professionals. To the extent available, existing data sets should be used to supplement indicators and variables derived from field sampling. These may include inventories and maps relevant to transportation project sites.

Cost: $600,000 ($150,000 for each of 4 projects)
Duration: 3 Years

APPENDIX

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