Aircraft Noise

1. A Cost/Benefit Analysis of Transportation Noise

Problem Statement:
While historical and current efforts to reduce transportation-related noise have been costly to develop, implement and enforce, the nature and magnitude of their specific costs have not been well documented or accurately measured. As a consequence, policy makers may not have been thoroughly informed with regard to decisions on the design of noise regulation and control strategies and the allocation of resources among different measures to reduce noise impacts. Maintaining support for the continued investment in noise reduction technologies, including noise modeling tools, and the development of effective noise regulation strategies is contingent upon developing a more complete understanding of the costs of transportation noise, including the cost associated with further reductions on noise and the economic impacts of residual uncontrolled noise. Likewise it is imperative to understand the measurable benefits of an effective, well-rounded noise control strategy which includes elements of source noise control, operational techniques and land-use planning, including the design and development of accurate prediction tools

Research Objective:
The objective of the proposed study is to determine how past funds have been spent with regard to transportation noise reduction and to make recommendations on how to best allocate future funds, taking into account of the potential benefits associated with particular decisions. The study will include a general account of past expenditures and a related evaluation of effectiveness. In short, the study will address the following three questions: (1) on what projects have noise-related funds been spent; (2) how effective were these projects at accomplishing their goal of noise reduction, i.e., what benefits were reaped; and (3) how are future noise-related funds best spent. In addition, this study will result in a guidelines document which will explain the process for conducting a noise cost/benefit analysis. This document will serve as a prototypical cost-benefit tool.

Cost: $400,000

Duration: 24 Months

2. *Development of a Methodology for Quantifying Transportation Noise Exposure in the United States*

Problem Statement:
Each year in the U.S., many millions of dollars are spent on reducing the exposure of Americans to various types of transportation noise and many governmental efforts are aimed at improving policies to manage transportation noise exposure. However, we have very little idea how many people are exposed to unwanted noise or how these exposures are varying over time. The last major studies to estimate noise exposure in the U.S. were conducted nearly forty years ago. Politicians, decision-makers, and the general public

need this information in order to make informed decisions about improving transportation noise policies and spending public funds on noise control projects. Thus, a real need exists for new studies to be conducted to estimate the current levels of noise exposure across the nation.

Research Objective:
It is proposed that a large-scale research program, using a combination of noise modeling and field noise measurements, be implemented to estimate the current levels of exposure of the U.S. population to aircraft, highway, and rail transit noise, and to forecast how these exposures are expected to change over the next several decades. Because of the size of this effort, however, it is proposed that a preliminary project be conducted to develop the research methodology and address various technical issues involved in implementing such a large-scale study. The results of the current effort would provide an assessment of the feasibility of quantifying transportation noise exposure and a detailed plan for conducting such a study.

Cost: $225,000

Duration: 24 months

3. Aircraft Noise Health Effects Study

Problem Statement:
There has been a steadily increasing concern over the past two decades about the adverse effects of exposure to transportation noise on the health of exposed populations. The magnitude of these effects have not been fully determined nor have the cost of the effects. Most of the concern has focused primarily on potential cardiovascular effects (e.g., hypertension, myocardial infarctions, and arrhythmia) and immune system deficiencies. In addition, exposure to transportation noise and the existence of any of these medical problems may predispose individuals to a higher level of susceptibility to adverse physiological effects from other stressors, including exposure to occupational noise, other environmental noises, and non-noise stressors. All of these concerns have been well documented in the scientific literature, mainly from studies conducted in Europe, and in the proceedings of various international scientific conferences such as those sponsored by the International Congress on Biological Effects of Noise (ICBEN) and the International Congress on Acoustics (ICA). The recent World Health Organization document, "Guidelines for Community Noise" (WHO, 2000), also reported serious concern about the possibility of adverse effects of community noise exposure on human health and strongly recommended reductions in exposure to community noise, especially in or near large cities.

Research Objective:
The current project would develop the detailed methodology for a prospective epidemiological field study of aircraft noise health effects. Although various possible adverse health effects and different transportation noise sources can be studied using a variety of research designs, the recommended approach is to conduct prospective

epidemiological study (i.e., a longitudinal field study) of possible cardiovascular effects due to exposure to high levels of aircraft noise. It is recommended that two groups of people living around major metropolitan airports (the exposed groups) and two control populations (the non-exposed control groups) be selected for inclusion in this study. It will be important to select the exposed and control groups so that there are differences in their aircraft noise exposure levels, but the total exposure to non-aircraft noise sources should be fairly similar. There should be at least a 20dB DNL difference in the total annual aircraft noise exposure between the exposed and control groups, and less than a 5dB DNL difference in exposure to other noise sources for these groups. Also, the subjects would need to be exposed to only the exposure levels which occur naturally in their environment in order to adequately protect the exposed subjects. That is, only adventitious exposure can be used, with no purposeful additional exposures being added during the study. Finally, expert epidemiologists would need to agree on the set of potential confounding personal ethnographic variables, which would need to be controlled through proper subject selection procedures. Examples of such variables include age, sex, health habits such as smoking, and existing physical conditions such as obesity, etc.

The subjects in this study should be followed for approximately ten years, with annual physical examinations and health questionnaires. The data collected each year would be analyzed and interim reports published. At the end of the field study, reports on the study conclusions would be published and the noise policy implications of the findings would be discussed in a series of national forums.

Cost: $350,000

Duration: 18 Months

4. Aircraft Community Noise Impact Below 65 dB DNL

Problem Statement:
Long standing noise assessment methodologies for determining noise impacts from, and community responses to aircraft flight operations have focused on areas within the 60+ DNL areas and only consider noise from flight operations. These approaches have been successful in measuring and predicting both noise impacts and anticipating community response in those areas relatively close to the airport, where aircraft noise is typically the dominate noise source. Beyond those areas, however, where aircraft noise is not as significant, there is less understanding of the effects of aircraft noise and the impacts of changes in flight operations. In areas with lower aircraft noise impacts slight changes in the number or path of flight operations may cause community responses that are not readily predicted or explained with current methodologies. These community responses may be due an increase in noise. They may also be motivated by increased number of flights or changes in aircraft path and altitude albeit with minimal changes in noise. To better understand community response to changes in aircraft operations resulting in levels below 60 DNL, more information is needed on the relationship between aircraft noise and the community's noise, flight frequency and aircraft proximity.

Research Objectives:
The objectives of this study are as follows:

(1) review available data from recent airspace and runway projects to determine accuracy of predicted impacts and community response with actual results;
(2) in light of findings evaluate the capabilities of impact predictions and recommend appropriate revisions; and,
(3) identify and recommend appropriate new impact predictions.

The study would result in a technical report addressing issues related to community noise impact below 65 dB DNL.

Cost: $275,000

Duration: 18 months

5. Best Practices for Sound Insulation Around Airports

Problem Statement:
Currently a large number of airports in the United States 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 or best technological practices from those airports further along in their sound insulation programs to assist those airports just beginning such programs. In addition, most airports manage these programs in very different ways. There has been no assessment of what techniques work best in various situations, including how various airports measure the success of a specific insulation program. In addition, most sound insulation programs in the U.S. focus on the use of new windows, new doors and air conditioning as the primary insulation techniques, and little effort has gone into looking at more state-of-the art approaches to sound insulation.

Research Objective:
The objective of this research is to identify, categorize, assess and document active sound insulation programs in the United States and other countries. This will include the identification of those elements of such programs that are most effective and those elements that are least effective. Similarly, it will include a review of the various approaches used by airports to quantify the success of their sound insulation program, including a review and compilation of the testing methods used to field-measure the effectiveness of specific insulated residences. The review will also include a synopsis of local building codes, which regulate the insulation of structures in the vicinity of airports. This particular element of the review will focus on the applicability and technical accuracy and sufficiency of published codes. Based on a review of current practices, a guidance document will be prepared to assist airports in setting up, successfully managing and quantifying the effectiveness of sound insulation programs. The guidance

documentation will emphasize current state-of-the art techniques with a goal of identifying more promising techniques that require future investigation.

Cost: $425,000

Duration: 18 months

6. Technical Tools to Support Land Use Compatibility Planning

Problem Statement:
Land adjacent to airports, highways, and rail transit lines needs to be developed so that noise-sensitive uses are prohibited and community development is planned, designed, and constructed in such a way that transportation noise impacts are minimized. In the U.S., the process used to support decision-making regarding noise-sensitive land uses is referred to as land use compatibility planning. However, State and local governments often lack the technical capabilities necessary to successfully conduct noise compatible land use planning. Research is needed to develop capabilities, which can be effectively applied to manage local growth and development with respect to transportation noise exposure. These tools should include educational materials, regulatory program guidelines, and the necessary technical and analytical capabilities required to properly conduct land use planning.

Proposed Research:
The objective of this research would be to develop technical tools and educational materials to be used by state and local officials and environmental planners in performing noise compatible land use planning. Examples of information to be incorporated as part of the envisioned toolkit would include references to appropriate noise policies and ANSI Standards regarding allowable noise exposures for various land uses and presentation of current "best practices" used by communities around the country. Examples of analytical capabilities to be incorporated into the toolkit include adequate noise propagation models and Geographic Information System (GIS) graphical representations of population distributions and existing land uses. This proposed project would result in a prototype land use compatibility planning toolkit ready for an initial test case involving land use planning in several representative communities and for various categories of transportation noise sources.

Cost: $250,000

Duration: 24 months

7. Synthesis of Noise-effects on Wildlife and Development of Impact Assessment Guidelines

Problem Statement:
In considering the effects of transportation noise on areas adjacent to highways, airports and railways, analysts normally give primary consideration to exterior areas of frequent

human use. However, transportation noise can also adversely affect wildlife populations. Extensive studies of noise effects on wildlife have been conducted, however an up-to-date compilation of related research does not exist. In addition, fundamental wildlife research is extremely costly, and the development of quantitative noise-dose and qualitative wildlife response relationships for a wide range of species is not economically or technically feasible. Information is needed on both the short-term and the long-term effects of transportation noise disturbance on wildlife. However, knowledge gained to date could be used to develop general guidelines for assessing noise impacts on wildlife.

Research Objective:
The objective of this study would be to develop a compilation of research conducted to date on the effects of noise on wildlife, with a specific emphasis on transportation noise. The effects of noise on different species will be examined. A comparison of work from differing researchers studying the same species will also be included. A particular emphasis will be placed on the differing responses to varied transportation noise sources, e.g., highway, aircraft and rail. Based on a review of the compilation, general technical guidelines will be developed for assessing noise impacts on wildlife. These guidelines will take into account issues such as mortality, breeding periods, reproduction, changes in habits, abandonment and other behavioral responses.

Cost: $325,000

Duration: 24 months

8. Study of Community Response to Non-Aircraft Transportation Noise

Problem Statement:
Current transportation noise policies in the U.S. rely heavily on scientific dose-response relationships between noise exposure levels and various community responses, predominantly "community annoyance". This is also the approach used in virtually every major country around the world and is a valid basis for environmental noise management decisions. It is also the approach recommended by the World Health Organization in their recent report, "Guidelines for Community Noise" (WHO, 2000). However, the database upon which the community annoyance prediction curve used in the U.S. (published as ANSI Standard S12.9, Part 3) for the most part contains only aircraft noise data because community response data for highway and transit noise exposures are scarce. The current U.S. database and community annoyance prediction curve also does not address changes in noise exposure and the associated community response as a function of the time of day, although it is well known that transportation noise exposure and human activities vary greatly throughout the day. These types of data are needed to support future improvements in U.S. noise policies.

Research Objective:
It is proposed that a field research program be designed and implemented to assess community responses to highway and rail transit noise, and to investigate the effects of these exposures as they vary throughout the day. The data obtained from this research

will then be used to develop community annoyance dose-response relationships for non-aircraft transportation modalities as a function of the time of day.

Cost: $750,000

Duration: 36 months

9. Research on Helicopter Noise Impacts to the Community

Problem Statement:
Helicopter noise has become an increasing problem in the United States. Over the past several years the FAA, under a mandate from Congress conducted a study of helicopter noise in urban environments in the U.S. The culmination of that study was a Report to Congress on the state of helicopter noise in the U.S. The study was of limited scope and hence the report was effectively a synopsis of research done to date. However, it included a comprehensive set of recommendations for additional research that is needed to better understand the helicopter noise issue. This needs statement focuses on recommendations in the Report pertaining to research on various helicopter operational procedures as a noise mitigation technique.

Research Objective:
As recommended for further research in the Report to Congress, this study would focus on the design and development of operational techniques and tools for mitigating helicopter noise. The target audience for these tools would be environmental planners, city planners, etc. The study would include a feasibility analysis of low-altitude aircraft tracking systems, the feasibility and expected effectiveness of an urban helicopter noise monitoring system and the development and documentation of quiet flying procedures for specific model helicopters which currently do not maintain such procedures. With regard to quiet flying procedures the documentation would focus on specific models of helicopter in various regimes of flight.

Cost: $450,000

Duration: 24 months

Highway Noise

1. Improve the Federal Highway Administration's Traffic Noise Model (FHWA TNM) to Expand Acoustical Capabilities

Problem Statement:
Since the release of the FHWA TNM, users have identified additional factors that affect highway traffic noise prediction. Improvement of the model's acoustical capabilities will allow a more accurate and efficient analysis of traffic noise impacts and development of more cost-effective noise mitigation.

Proposed Research:
Develop acoustical improvements to the FHWA TNM and noise analysis techniques that address the following requirements:

Effects of Engine Compression Brakes

Trucks traveling in the downhill direction, and those slowing down on level roadways, often used noisy Engine Compression Brakes. However, heavy trucks traveling in the downhill direction are treated in the FHWA TNM in a manner similar to those on level roadways at constant speeds, i.e. there is no correction to account for the noise increase due to Engine Compression Brakes. The research will develop algorithms to account for the influences of these Engine Compression Brakes.

Effects of Structure-Reflected and Generated Noise

Receptors adjacent to bridge structures are often subjected to undesirable noise levels, even after noise barriers are constructed on the structure. The cause of such noise is unclear, e.g., does the noise result from vibration of the structure deck, does the noise result from factors related to different structure designs (open beam, box girder, reinforced concrete slab, etc.), or are other factors involved? The research will determine the mechanisms and/or sources of the noise emissions, and if there are ways to mitigate the situation. Another issue relates to the degree of influence that may exist due to the open median area between parallel bridges, and how this may influence overall noise levels. The research will determine the source or sources of noise/vibration emissions from bridge structures, and quantify the differences that may be associated with various bridge designs. Feasible mitigation measures and design approaches to minimize structure noise will be evaluated.

Noise Associated with Weigh Stations, Rest Areas, Service Plazas, and Toll Facilities

Traffic and activities in these areas affect adjacent property owners. Techniques need to be developed and evaluated to address noise-producing activities, such as truck idling, express lanes, toll booth activities (including associated acceleration and deceleration), etc. The research will develop measurement and modeling techniques that accurately address noise associated with these activities.

Effects of High Volumes of Trucks

The FHWA TNM sometimes overpredicts noise levels adjacent to multi-lane roadways with high volumes of heavy trucks. It is felt that such overpredictions may result from a substantial number of vehicles being in the lanes farther from the receptor, thus being shielded by trucks travelling in the lane nearest to the receptor. Existing and future data will be evaluated to determine whether modifications to traffic noise analysis techniques are necessary.

Improvements will allow a more accurate and efficient analysis of noise impacts and development of more cost-effective noise mitigation.

Cost: $450,000

Duration: 36 months

2. Improve the Federal Highway Administration's Traffic Noise Model (FHWA TNM) Through Additional Validation Studies

Problem Statement:
The FHWA TNM is a state-of-the-art prediction model that is used to address many analysis complexities, e.g., vehicle emissions, roadway geometry, site characteristics, etc. Validation studies are necessary to ensure accurate analysis of these complexities.

Proposed Research:
Develop improvements to the FHWA TNM and traffic noise analysis techniques to address the following:

Effects of Irregular Terrain

Highway sites may include terrain with undulations of varying size, with slopes to and from the roadway to the receiver, or with sharp discontinuities (cut or elevated roadway). There is a need to validate existing traffic noise analysis techniques to ensure that irregular terrain effects are accurately considered.

Vehicle Source Energy Distribution

In the FHWA TNM, the total sound energy emitted by a vehicle source is apportioned between two sub-sources before being propagated out to receptors. There is a need to determine if there is a significant dependence of subsource-height relationships on vehicle speed, pavement types, graded versus level roadways, or interrupted-flow conditions.

Improvements will allow a more accurate and efficient analysis of noise impacts and development of more cost-effective noise mitigation.

Cost: $300,000

Duration: 24 months

3. Understanding Tire/Pavement Noise Generation Mechanisms

Problem Statement:
European trials, which have concentrated primarily on pavement experiments, have found that a 10 dB reduction in noise generation is possible with some advanced porous highway and rubberized highway concepts. However, these investigations have been based on large scale field tests with limited number of alternatives. The tire carcass has been studied for its radiation characteristics. This aspect of the tire is reasonably well understood. There is some potential for developing a quieter tire in the frequency range below 500 Hz by building a tire that does not radiate sound effectively. However, the interaction of the tire and pavement has not studied extensively, primarily because of the difficulty of making measurements in the contact patch region, and partially because the behavior of the tire and pavement is difficult to model. Above 500 Hz, holography measurements indicate that the sound generation occurs largely at the entrance and exit of the tire/pavement contact patch. These mechanisms of noise generation are not well understood. If the mechanisms were better understood, it is possible that significantly quieter pavements, which are also durable, safe, and easy to construct, could be developed.

Research Objective:
Better understanding of the noise generation mechanism is required. These mechanisms are believed to include air pumping, tread impact, tread release, and tread/pavement stiction. Laboratory studies are necessary to measure each of these mechanisms under controlled tire/pavement conditions. Measurements should be made of tread block motion, air pumping, dynamic pavement strain, and near field acoustic radiation. Such testing is necessary on all types of pavement surfaces, including European quiet pavement alternatives.

US research effort is also required to consider the potential for use of European pavement technology in the US. European construction approaches and materials do not directly translate to US construction techniques or durability and safety standards. Adaptation and testing of these approaches for possible US application is needed. These tests should include both laboratory and field testing.

Duration: 36 months

Cost: $350,000

4. Methodology to Measure the In-Situ Acoustical Properties of Noise Barriers, Pavement, and Sound Propagation.

Problem Statement:
Recent advances in highway traffic noise abatement capabilities and noise modeling have led to a greater need for descriptive measures of the acoustic properties of key site variables in the vicinity of the highway . Such key site variables include the acoustical properties of the noise barrier; local ground properties, and acoustical properties of the

road surfaces. These variables cannot be measured *in situ* using conventional methodologies. At present, these important variables are being approximated from laboratory testing or general trends reported in the literature. Further, certain sound property measurements requiring "before" and "after" measurements are often imprecise due to the challenge of achieving source equivalence. Individual projects must rely on this data because there is no low-cost, practical method currently available. This leads to errors in prediction, which translates to inaccurate modeling of traffic noise, especially during the design of noise barriers.

Research Objective:
Develop instrumentation and methodology based on modern signal processing techniques to identify the key acoustical properties of a site needed for traffic noise prediction. Techniques are available for making these measurements during periods of heavy traffic flow because of the patterned impulse nature of the signal. The Reflective Index should provide needed information to allow determination of the important acoustical parameters such as noise barrier absorption and local ground impedance. With the proper equipment setup, these in-situ measurements supply important relationships between the results determined in laboratory testing and allow more exacting input to support new highway noise prediction models in a practical way. Investigation will include:

- Definition of the methodology required to perform *in-situ* measurements of the key acoustical properties of typical highway noise barriers, ground properties, and roadway surfaces, as well as the entire propagation path from source to receiver;
- Testing of multiple sites should be done to allow preliminary comparison of the results of the derived methodologies to the information now being used and to allow various wall textures and pavement surfaces to be tested. Specific instrumentation requirements, and setup methodologies should be explored and documented during these field measurements.

Duration: 24 months

Cost: $400,000

5. Atmospheric Effects on Highway Traffic Noise Propagation

Problem Statement:
Studies by several research groups have shown that the atmospheric refraction and scattering effects that occur on the sound wave propagating from a highway traffic source is a source of error during prediction and measurement. It is possible for noise levels to change by as much as 10 decibels or more at a receptor location due to these atmospheric effects. Due to a lack of research, the FHWA TNM, only allows the user to input data for temperature and humidity. Existing FHWA modeling policy requires the use of neutral atmospheric conditions.

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

1. Utilize existing data and/or perform measurements of noise levels at varying distances and heights from the vehicle path along with data of wind speed, wind direction, and temperature. Site geometry should be flat and open, such that only ground effects, geometric spreading and atmospherics would affect propagation. Normalization of ground effects and geometric spreading can be accomplished, with the only remaining variable being atmospherics.
2. Using the measurement data from Task 1, along with data from other relevant studies, develop a prediction scheme.
3. Perform validation of the prediction scheme for traffic noise at two "real world" sites along existing highways, 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.

Funding this research would provide valuable information for the FHWA TNM, allowing increased prediction and calibration accuracy at greater distances from a highway than currently possible. This would increase the credibility of the analysis to the public and provide a more complete picture of traffic noise impacts.

Cost: $300,000

Duration: 24 months

6. Develop a Methodology for Determining Tire/Pavement Noise Characteristics

Problem Statement:
Traffic noise negatively impacts the quality of life for many communities adjacent to highways. Increasingly, communities are rejecting roadway capacity improvement projects, based in part on existing noise levels and partially on the perception that additional, noticeable noise will be generated by the project. The noise generation characteristics of different type of pavements can vary as much as 6-9 dB.

A draft ISO standard has been developed to measure tire/pavement noise *in situ.* This technique allows quick evaluation of pavement and evaluation of the long term noise mitigation effect of quiet pavements. This ISO standard was developed without any US testing. There is also no standard tire for noise testing using the ISO standard in the USA. Effort must be invested to identify a standard tire for use in tire/pavement noise testing. Testing must also be done to evaluate the ISO standard for application in the US.

Research Objectives:
The research objectives should be to:

1. Develop a standard tire for application in tire/pavement noise studies
2. Develop a standard method for testing the tire/pavement noise levels

Tires manufactured for automobiles have many variations. An effort will be required to find a tire which is reasonably representative of the complete population and which reliably ranks pavement for tire/pavement noise characteristics.

The ISO standard for measuring tire/pavement noise is a trailer borne microphone array referred to as the close proximity method (CPX). The data taken already in Europe and additional data taken in the USA will be evaluated to ensure that the CPX approach, or a US alternative, is a reliable predictor of passby noise. An alternative using a sound intensity probe mounted to a vehicle to capture and analyze spectral data should also be considered.

Cost: $300,000

Duration: 36 months

7. 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. The cause and nature of the perceived increase in noise levels is not fully understood.

Proposed Research:
Comprehensive studies of noise level magnitude, annoyance, and in particular 1/3 octave-band frequency analysis of the noise source spectrum opposite a reflective noise barrier is recommended. These quantitative analyses will then be used to determine if the magnitude and/or composition of the noise level actually changes, or whether the complaints are triggered by the psychological phenomenon of "barrier envy" (nearby residents are not receiving a noise barrier when their neighbors do).

Several state Departments of Transportation 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 especially 1/3 octave-band frequency analysis and meteorological data, traffic noise source and reflected spectra should be analyzed. Results should be assessed against current prediction methodologies. The analysis should identify whether or not a measured shift in the overall noise level and/or frequency content occurs for a given set of traffic operations. Evaluations should consider if the presence of a phenomenon varies with distance, or is influenced by geometric or physical parameters such as barrier height, and surface roughness and by vehicle type and under variable traffic mix scenarios (i.e. high vs. low truck percentages , low vs. high speed traffic, etc.).

Cost: $300,000

Duration: 24 **months**

8. Improve the Graphical User Interface (GUI) of the Federal Highway Administration's Traffic Noise Model (FHWA TNM)

Problem Statement:
The FHWA TNM is the current highway traffic noise prediction model that incorporates state-of-the-art acoustical algorithms in a program with a Microsoft Windows environment and internal Computer-Aided Design Drawing capabilities. Since the release of FHWA TNM, users have gained training and experience in its use and have indicated a desire and need to improve the model's GUI. Improvement of the model's software capabilities will allow a more accurate and efficient analysis of traffic noise impacts and development of more cost-effective noise mitigation.

Proposed Research:
Develop improvements to the FHWA TNM that address user-identified GUI requirements. This effort will require extensive communication and coordination with FHWA TNM users and, if necessary, could require modifications of model source code.

Improvements will allow a more efficient analysis.

Cost: $150,000

Duration: 12 months

9. Rumble Strip Noise Reduction

Problem Statement:
As a safety measure many SHA's have installed "rumble" strips on paved shoulders of many highways. Designed to alert tired or inattentive drivers that have departed from the travel lane in time for them to safely recover, rumble strips can create an undesirable noise level at adjacent residential areas. While rumble strip noise levels have been researched in the past, this was only to assess the level generated at a variety of distances away from the roadway, Ways to reduce the radiated noise levels from rumble strips,

while maintaining the necessary noise level interior to the vehicle, needs to be investigated.

Research Objective:
The objective of this research project would be to identify alternative designs that could effectively alert errant drivers that they are leaving the travel lane without raising the noise levels at adjacent properties. Phase I would require *in-situ* measurement of the current design to establish a base line noise level. Phase II would test alternative designs under field conditions. Phase III would test alternative designs under field conditions and Phase IV would result in a report of the results.

Cost: $100,000

Duration: 12 months

10. Noise Barrier Costs

Problem Statement:
Cost is a major element in the determination of the reasonableness of constructing a noise barrier. State decisionmakers use many factors in establishing barrier cost, and these factors may vary by state. Examples of this variation include the manner in which barrier costs are reported, e.g., lump sum, cost per square foot of barrier, by individual construction items, etc., and the effects of incidental items on cost, e.g., right-of-way, utilities, landscaping, maintenance, drainage, safety, aesthetics, design, project mobilization, maintenance and protection of traffic.

Proposed Research:
A synthesis is necessary to identify the factors that decisionmakers use in determining noise barrier cost. The synthesis should lead to development of best practice guidance for barrier cost determination.

Funding this research would provide valuable guidance to those involved in evaluating noise barrier reasonableness. This would increase the credibility of the analysis and the evaluation techniques.

Cost: $100,000

Duration: 12 months

Rail/Transit Noise

1. Development of a Multi-Modal Noise Model Specifications

Problem Statement:
As population growth and urban sprawl continues in the U.S., our transportation infrastructure is continually expanding. Airport authorities are building new runways and

adding terminals, interstate roadways are being widened and new roads are being built. Rail corridors are being expanded and upgraded to meet the growing demand for regional transportation. The ever-expanding transportation infrastructure in the U.S. comes at a substantial cost to the environment, particularly in the area of noise. In fact, in a recent survey of the 50 major US. airports conducted by the General Accounting Office (GAO), it was concluded that noise is the primary environmental obstacle to growth, both now and in the future.

The traditional approach of conducting noise analyses separately by transportation mode is becoming more and more inappropriate. Conventional wisdom has historically dictated that if a noise study was being conducted near an airport all one needed to do was conduct an INM analysis. Similarly for a highway noise study use of TNM, or its predecessor STAMINA was all that was needed. A substantial portion of the U.S. population is subject to the combined effects of noise from more than one type of transportation source. In many communities noise from aviation, highway and rail systems is commonplace.

Unfortunately, there is currently no methodology for simultaneously assessing noise from aircraft, highway and rail sources. This can result in inaccurate predictions of the noise environment at locations in the vicinity of multiple transportation sources. There is a recognized need for a Multi-Modal Noise Model (MNM) which can be used to compute the composite noise from multiple transportation sources.

Research Objective:
The objective of an MNM would be to provide the noise analyst with an easy-to-use, seamless tool which would allow the assessment of noise impacts associated with integrated transportation corridors which include noise contributions from aircraft, highway or rail sources. Most of the building blocks currently exist for the model, although development of a rail noise model compatible with the TNM would be necessary. The research should identify the necessary resources for model development. The final report should include a detailed description of: (1) the MNM input/output requirements; (2) the MNM GUI, including sample user windows; and (3) the required modifications to TNM to support a rail noise computational capability, including the identification and review of existing rail noise databases.

Cost
$150,000

Duration:
12 months

2. Directive Transit Vehicle Warning Systems

Problem Statement: Transit vehicular warning horns are relatively omni-directional and can be a source of annoyance in areas of the community adjacent to rail lines. For example, train horns sounded before grade crossings can have significant impact on

nearby neighborhoods. In some cases whistle bans have been enacted, but with the unfortunate consequence of increased accidents. More directive horns can "focus" the sound toward the ideal target area where it is needed while minimizing community impact in other directions.

Research Objective: Design and demonstrate examples of directive warning systems for locomotives and transit vehicles consisting of phased arrays of horns using well established array theory. Establish practical tradeoffs between the degree of directivity achieved, ruggedness and cost. These designs can then be assessed both theoretically and empirically in terms of community noise reduction that they can provide in terms of standard measures including L_{max}, SEL, $L_{eq,}$ and L_{dn} for a variety of transit vehicles.

Cost:
$250,000

Duration:
18 months

3. Simple Construction Site Noise Prediction Procedure

Problem Statement:
No longer can project proponents simply dismiss construction noise as a short-term necessary consequence. Today communities are more politically organized and regulatory agencies are more sensitized regarding the need to successfully mitigate construction noise, or else face the very real threat that distressed community groups may bring construction progress to an expensive and embarrassing halt. To enhance the construction noise control state-of-the-art, it is suggested that an improved construction noise prediction model be developed. The model currently in general use today stems from old EPA methods promulgated in the 1970's which are based on noise emission source strength levels associated with generic types of equipment. Shortcomings in the current model include the fact that existing equipment noise databases are expressed only as maximum (Lmax) broadband A-weighted emission levels, which oversimplifies the importance of frequency (tonal) effects, and does not address warning devices such as back up alarms. The temporal (time varying) changes in noise as equipment cycles through work operations are currently only estimated from acoustic usage factors (U.F), or the percent of time that equipment is working at full power. Moreover, with better mufflers and engine housings, noise emissions associated with today's typical construction equipment have changed significantly over the course of the past 30 years. Thus, the current method of modeling construction noise using metrics of interest, such as Leq or L10 percentile levels, are coarse estimates at best.

Fortunately, modern noise measurement instrumentation, combined with the unique field data collection opportunities at numerous construction projects, provide an opportunity to quickly develop a much-improved construction equipment noise database and prediction model algorithm on a spectral basis. The frequency-dependent effects of noise barriers, distance and ground losses, atmospheric absorption, and interaction with structures or

buildings can be modeled much more accurately. Usage factors could potentially be eliminated by defining a variety of generalized, process-related construction activities. Resulting construction noise predictions will still be able to be evaluated against established noise criteria limits, which are typically expressed in broadband (A-weighted) levels. It is envisioned that such a model can be developed in spreadsheet format using commonly available programs such as Excel or Lotus123, or as a new TNM module. Input geometries in the model could be graphical or tabular (as with TNM), and construction equipment of interest could be selected from database lookup menus.

Research Objective:
Develop a new construction equipment noise spectral database and TNM prediction module.

Cost:
$450,000

Duration:
24 months

4. Data Synthesis for Vibration Insertion Loss Afforded Tie and Ballast Trackwork with Ballast Mats, Tie Boots, and Trenches

Problem Statement:
Increased emphasis on a national scale is being placed on expansion and refurbishment of fixed-guideway transit systems, especially steel rail/steel wheel formats. This has exacerbated the need for accurate information regarding effective methods of reducing the potential adverse effects of transit-induced ground vibration. Many existing rail transit systems are in close proximity to dense residential and other vibration-sensitive development. New rail systems that are in the planning, development, and design stages are often located in urban environments very close to vibration-sensitive use. This juxtaposition of seemingly incompatible use is not "encroachment" in the traditional sense; it is actually desirable and necessary to place these systems adjacent to and within origin and destination uses such as residences, medical facilities and high-tech research and development and manufacturing areas. Thus, the ability to co-locate transit systems with origin and destination uses, without creating unacceptable adverse groundbourne vibration or noise, is increasingly important.

While the efficacy of the most sophisticated (and most expensive) vibration isolation systems such as floating-slab are well documented, there is a definite need for access to comprehensive information regarding performance and applicability of the more practicable alternatives of using ballast mats, tie boots, and trenching methods of vibration isolation. This will allow the system designers, environmental analysts, funding agencies, and the affected public a better understanding of the overall effects of the rail transit system and the cost/benefit aspects of providing a transit system that is compatible with vibration-sensitive uses.

Research Objective:
Synthesize a comprehensive data base addressing initial and long-term technical effectiveness, initial and life-cycle costs, construction concerns and delay mechanisms, and applicability preferences of using ballast mats, tie boots, and/or trenching approaches to vibration isolation of rail transit systems. The synthesis could include a meta-analysis of existing research and where new research might be required, especially in regard to performance characteristics of candidate mitigation options in various soil types.

Cost :
$75,000

Duration:
9 months

5. Vibration Dose-Response Curve Development

Problem Statement:
Vibration propagation through the ground is physically very similar to the propagation of noise through the air. Vibration and noise are similar in other respects as well, however the criteria by which scientists judge the acceptability of noise and vibration are quite different. For example, environmental noise is typically judged on the basis of cumulative noise exposure using the Day Night Average Noise Level (L_{dn}) metric. The L_{dn} is essentially a 24-hour average with a 10-decibel nighttime penalty to account for people's increased sensitivity to noise at night. The well-known "Schultz" curve is a dose-response relationship between airborne sound levels and percent of people highly annoyed. This curve forms the basis for the expected change in noise impact due to either increasing noise level or the frequency of occurrence and duration of noise events. However, the vibration impacts of transportation projects are assessed solely on the basis of maximum vibration level, and do not generally take into account the frequency of occurrence of the events. Attitudinal surveys for vibration effects, similar to surveys used in the "Schultz" curve development, would be required to develop such a vibration dose-response curve.

Research Objective:
Develop a dose-response curve for vibration and ground-borne noise to assess the change in annoyance due to a change in the frequency of occurrence and duration of vibration events.

Cost:
$500,000

Duration:
24 months

6. Transit Warning Signal Dose Response Data Development

Problem Statement:
The specific noise issue in the vicinity of at-grade rail crossing are locomotive warning horn and crossing bell soundings causing significant noise impacts. The acoustic signatures of these warning devices are unlike the transportation vehicle exposures that are the basis for the dose-response surveys that guide most judgments of environmental noise acceptability. For horn soundings, the distance to the 65 dBA Ldn noise contour can extend as far as 500 to 1000 feet from the grade crossing and can encompass a large number of homes. Crossing bells, while not reaching as far into the community as warning horns are still a substantial source of annoyance and complaints from nearby neighbors. It appears that existing criteria do not adequately reflect the potential adverse effects caused by these sources.

Proposed Research:
The dose-response data upon which the Schultz curve and its variations are based do not include locomotive warning horn noise or crossing bell noise. This is a shortcoming in the basis for assessment of transit project noise impacts. It could be, for example, that the "startle effect" of warning horns would result in a 1 dBA allowable increase. Or perhaps the Ldn is the wrong metric to use. A comprehensive attitudinal survey/noise measurement program should be conducted to address these issues.

Cost
$230,000

Duration
12 months

7. Program for Reducing the Noise from Corrugations in Transit Rails

Problem Statement:
The operation of steel-wheeled transit vehicles on steel rails may develop short-pitch corrugation of the rails. The interaction of the wheels rolling over the corrugated rails generates noise with a tonal component, which is usually harsh and uncomfortable for transit patrons and obtrusive to wayside receivers, and has been associated with “singing rail” condition. Several variables may contribute to the development of corrugation, including rail car suspension components, wheel composition and resonance characteristics, rail metallurgy, tie spacing (both average distance apart and variation), tie composition, tie or rail fixation, roadbed composition, and possibly other unknown elements. Rail corrugation eventually reaches the point where noise exceeds reasonable levels and the nearby community complains. Current practice is to remove rail corrugation by grinding the rail to restore the original profile. On some rail transit properties, a more sophisticated grinding program is followed, which uses multiple profiles to equalize the wear across the wheel tread, and special profiles for curves, which also reduce wheel wear. This program, where rails are ground every two to three years, reduces corrugation and controls rutting of the wheel tread. However, maintenance costs would be reduced if a design solution or preventive measures besides rail grinding could be found.

Research Objective:
Significant research into this topic has been conducted, and is ongoing elsewhere in the world. A first objective in the US should be to evaluate the state of research elsewhere and determine its applicability to US needs. US research resources can then be aimed at building upon existing research and integrating these efforts towards achieving solutions. In general this research should be directed towards determining the causative relationships of various design parameters or conditions that contribute to short-pitch rail corrugation. These include track support stiffness, lateral stiffness, damping properties, tie spacing, wheel resonances, rail and wheel metallurgy, tie characteristics, etc. This substantial effort will result in development of efficient and effective design approaches and methods for preventing corrugations.

Cost
$500,000

Duration
36 months

8. Transfer Mobility Measurements and Testing Techniques

Problem Statement:
Transfer mobility measurements are used to help predict vibration and ground-borne noise impacts from transit and rail systems and also to evaluate the effectiveness of vibration mitigation techniques. Current methods for measuring transfer mobility between planned or existing transit facilities and nearby sensitive receivers present a number of problems. For example high background vibration levels in busy urban environments make such measurements and analysis difficult and time-consuming. Existing required measurement equipment is cumbersome and often presents logistical roadblocks. Newer, less burdensome measurement techniques need to be investigated.

Research Objective:
Investigate and recommend acceptable test parameters of current test methods such as required signal coherence, and explore newer alternative test methods such as Maximum Length Sequence technology in order to reduce time and expense with improved measurement quality.

Cost:
$75,000

Duration:
6 months

9. Noise and Vibration from Automated People Movers (APMs)

Problem Statement:
Over 100 APMs of various kinds and sizes now operate around the world. Urban planners, engineers, and architects often consider using APMs to link activity nodes and serve remote parking and transit. They have little data on actual experience with noise and vibration from APMs. This discourages them from considering APMs in general, and also from specific applications which integrate stations and guideways into urban buildings. A better understanding of the noise and vibration characteristics of APM's may lead to their more widespread use.

Proposed Research:
Define a sample range of APMs and collect consistent, objective data on noise and vibrations (some of which may already exist) in a form useful to planners, engineers and architects. Compare these findings with LRT, HRT, bus and other forms of public transport. Produce a user-friendly database and guidebook.

Cost:
$125,000

Duration:
12 months