RESOURCE PAPER

Sustainability, Including Climate Change: Cause and Effects

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The terms "sustainable development" and "sustainability" have come to encompass a wide variety of environmental, economic, and social concerns. An often-cited definition of sustainable development comes from the 1987 Brundtland Commission (United Nations World Commission on Environment and Development).

> A sustainable condition for this planet is one in which there is stability for both social and physical systems, achieved through meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Notions of sustainable development have become associated with a wide array of issues and public policy concerns. Although these applications have often been related in their fundamental emphasis on ensuring a habitable planet, some have focused more on ecological and natural resource needs for achieving this goal, whereas others have stressed the social and economic dimensions of this goal. In transportation, the 1997 National Research Council–Transportation Research Board (NRC–TRB) report, *Toward a Sustainable Transportation Future*, employed a more conservative approach, focusing on disturbances that threaten large and irreversible environmental consequences.

A broader view is now emerging. The World Bank, in a 1996 report on transportation, articulated this broader definition well, identifying three components:

1. Economic and financial—includes the issues of adequacy of transportation infrastructure funding, organization, and scale.
2. Environmental and ecological—includes issues of how transportation investments and mode options influence travel and land use patterns and how these in turn influence energy consumption, emissions, air and water quality, and habitats.
3. Social—emphasizes adequate access to transportation services by all segments of society.

A forthcoming (2002) NRC/TRB report from the Surface Transportation Environmental Cooperative Research Program Advisory Board embraces this broader approach.

In practice, though, sustainability does not lend itself to a precise definition. It is used here, as elsewhere, to signal a more desirable future, in its broader sense. However, even this reference to a more desirable future raises questions: are we speaking of a future that is no worse than today's, implied by the word sustainability, or are we speaking of an better future. Most would say we should aim for a better future.

CONTEXT: SOME SUCCESS, MORE CHALLENGES

The United States has enjoyed a remarkable, prolonged period of economic expansion since World War II. The standard of living for the average American has increased substantially,

aided by continuing transportation improvements. Population has also grown substantially, increasing by 130 million in the past 50 years. This economic and population growth has led to even more rapid expansion in travel.

Automobiles, trucks, and highways have been the dominant means of surface transportation in the United States throughout this period and have played important roles in supporting and shaping the nation's growth and expansion. They have heavily influenced our consumer goods economy, development patterns, and popular culture. Access to a private vehicle has become the rule rather than the exception for those of driving age, and today more than 95% of our person-trips are by automobile. Truck usage also has grown and now accounts for more than 90% of all shipments. The distances traveled also are increasing. Since 1970, Americans have more than doubled total vehicular travel, and truck travel has more than tripled, with annual vehicle travel by heavy combination trucks nearly quadrupling in that 30-year period. In the United States, there are now more than 200 million vehicles traveling 5 trillion miles per year.

This increased travel translates to increased accessibility, mobility, and economic activity, which is largely beneficial. However, it imposes large direct and indirect costs on society.

The direct costs for expansion of the transportation system have been significant, with considerable investment in infrastructure, facilities, vehicles, and energy. However, even with this huge investment, many urban transportation facilities have become or are becoming even more congested. Much valuable time is lost in heavy traffic and more energy is consumed.

The indirect effects are becoming increasingly troubling. The population growth of more than 130 million in the last 50 years has been largely accommodated on the urban–suburban fringe; consuming land formerly devoted to farms, ranches, forests, and range. In addition, many center cities have lost population as household size decreased and living space expectations increased. More travel also threatens safety and environmental quality.In addition, because it relies so heavily on the use of private vehicles, some segments of society are find themselves marginalized (the percentage of households without cars dropped to only 8% in 1995, but those without cars are even more marginalized than before because of fewer transitoptions).

These indirect effects include increasing dependence on insecure petroleum sources, increasing emissions of greenhouse gases, more pollution sources, and greater ecological threats. Transportation already accounts for approximately two-thirds of the petroleum consumed in the country, and the amount continues to increase as we travel more in larger vehicles. Greenhouse gas emissions fromtransportation in the United States continue to grow and are expected to more than double in the next half-century. Highway safety has improved significantly; however, 40,000 people continue to be killed in crashes annually (motor vehicle crashes are the seventh leading cause of death nationwide). Roads connect all parcels of land in the country and are estimated to affect the ecology of more than one-fifth of the nation's land area. The high reliance on the private vehicle for travel along with population growth, fewer persons per dwelling, and increased housing space per individual, have been significant contributing factors in the broad spread of urbanized land areas. The amount of land devoted to residential and commercial land, parking, and streets is increasing at a far faster rate than population, although it is important to note that road mileage is increasing only 0.2% per year.

In addition, whereas increasing reliance on private vehicles provides greater access to an increasing proportion of the population, it marginalizes others. Indeed, the costs of owning and operating personal vehicles consumes 19% of the average American household's income—equal

to the amount spent on food and clothing combined, and triple that for medical care. Not all can afford to own and operate their own vehicles, and some cannot drive. Approximately 8 million households are currently without vehicles and these are often smaller households with older people, often women, living alone. A substantial proportion comes from among disadvantaged minority populations, often immigrants, living in center cities. New York City alone accounts for a significant segment of the non-car-owning population. In center cities, the number of households without vehicles can reach as high as 40% among minorities. People who cannot drive have limited access to jobs, services, education, and recreation. Older people, low-income people, and minorities bear a disproportionate share of these adverse impacts.

In summary, heavy auto use and the outward expansion of metropolitan areas, although improving mobility for many and offering opportunities for better and lower-cost housing, create a broad range of threats: air and water pollution, waste disposal, heavy energy use, fragmented farmlands and habitat, and community disruption. In turn, these problems can adversely affect ecosystem health. The overall quality of life improves for some, but disadvantages result for others.

An effect that is particularly challenging and merits special attention is climate change. It is a unique problem for the U.S. transportation sector because it is now recognized that actions taken here in the United States are likely to have important environmental (and economic) implications elsewhere. The U.S. transportation sector as a whole accounts for about 5% of all the CO_2 emitted by human activities worldwide. Although this percentage appears modest; however, no other energy use sector in the United States or elsewhere in the world accounts for a significantly larger portion of global CO_2 emissions. The challenge of creating institutions and mechanisms for reducing greenhouse gases affects virtually all activities and requires not only regional and national cooperation, but international cooperation as well.

Concerns about energy, the environment, safety, and social impacts have led to the enactment and creation of a wide variety of national and state laws, rules, and institutions, including the National Environmental Policy Act of 1969, Clean Air and Clean Water Acts as amended, Corporate Average Fuel Economy standards, California's Zero Emission Vehicle mandate, Federal Environmental Justice programs, and various rulemaking by the National Highway and Transportation Safety Administration. The provisions of successive Federal-Aid Highway Acts, especially the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21), have called for stronger roles for metropolitan planning; systematic consideration of social, economic, and environmental effects; protection of parklands; and more public engagement in planning. Certainly progress has been made in mitigating the adverse consequences of motorization and expanded transportation activity; the air and water are cleaner, species have been protected, accident rates have been reduced, and many other adverse impacts have been avoided or mitigated.

However, these policies have not yet produced what could be labeled a "sustainable" transportation system. Many indicators are headed in the wrong direction. Traffic congestion, energy use, and greenhouse gas emissions have worsened as population, vehicle size, and travel increased. Concerted efforts to improve and expand public transportation in recent decades have slowed and even reversed in many communities; but even so, only about one-half of the communities in the United States have public transportation systems, and the country as a whole has the lowest share of transit use of all the advanced economies, at only 2% of total travel.

The strains and challenges confronting the transport sector will be aggravated in the future. Unlike most other industrialized countries, the United States is expecting continued

population growth. The U.S. population is predicted to grow by 60 million in the next 25 years (close to 1% per year), with most of that growth in metropolitan areas. Annual passenger-miles traveled are predicted to increase even faster than the population or the economy, swelling from 5 trillion miles in 2000 to 8.4 trillion miles in 2025. Conversely, the number of roads and lane-miles of roads are expected to grow very slowly. Transit use, although expected to grow, is not expected to keep pace with population growth.

TOWARD A RESEARCH AGENDA

As the 2002 National Research Council–TRB report observes, "Our nation's collective vision of a transportation system that is efficient, equitable, and environmentally benign is clear. But we have no strategy to get there." The nation must find ways to deliver a transportation system that simultaneously promotes economic growth, adds to the health of communities and individuals, is safe, uses energy efficiently, and enhances the natural environment.

New approaches will certainly be needed. The congestion, air pollution, and energy dependence of current approaches already impose high costs on the nation's global competitiveness, economic security, and human and environmental health. Growth will add to the challenges and innovative responses will be needed if we are to maintain and improve the quality of life for all Americans.

Emerging technologies, regulatory actions, policy innovations, travel behavior changes, and new planning processes offer significant opportunities for improvement. Some options are obvious to transportation professionals, but those with greater impact require a sea change in public attitude. Our decentralized democratic style of government and our embrace of individualistic freedom undermine many changes that have large social benefit, but inhibit personal desires. In any case, relatively little is known about the practical application of these options and whether and where they will succeed.

In a broader sense, there is incomplete knowledge within the scientific and social science fields about the extent to which humans are changing the natural and social environment and the long-term implications of these changes on the well being of future generations. Considerable more attention and resources are needed to examine the trade-offs between benefits and costs and the most desirable strategies for enhancing the transportation system.

The 2002 NRC–TRB Advisory Board report concludes [draft]:

> We need a better understanding of vehicle and fuel technologies, highway design and operations, travel behavior, development patterns, and their environmental consequences. We need improved methods for analysis, forecasting, and other decision support tools. We need to improve and alter methods of finance, environmental education, and management systems. We need to modify institutions and regulatory approaches, and in some cases create entirely new ones, to deal with newly prominent problems such as climate change and to effectively manage rapidly changing technologies and fuels. We need to devise ways to mitigate the environmental harm that has already occurred from past practices, and to improve the environmental performance of future actions. More broadly, we need to study the effects of alternative approaches in transportation, land development, and the environment, and to document their efficacy. Finally, we need to put the

> findings of research into practice and create a system of continual improvement through renewed research and its implementation.

The 2002 [Draft] Advisory Board report lays out six critical research areas in transportation and the environment: human health impacts, effects on nature, land use/transportation issues, effects of new technologies, distribution issues, and planning and institutional issues.

The Advisory Board has concluded, based on its review of the situation, that the current state of knowledge and the tools available for environmental assessment are inadequate to the tasks ahead. They are failing the urgent test of assuring informed and effective decisions on transportation and the environment. Briefly stated, the Advisory Board finds that

- The scale of investment in environmental research related to surface transportation is far too small in relation to the scale of transportation activity and its impacts.
- Coordination of the research that does take place is insufficient to get the greatest benefit from the research effort or to ensure that gaps in the research agenda are filled.
- The dissemination of research results is inadequate and the practical implementation of research findings is too slow, with the result that current practice is not up to date and opportunities for improved performance are being missed.
- A long-term strategy for systematically addressing the effects of transportation on the environment has not been fully developed or implemented; current policies and investment strategies have tended to focus on short-term solutions.

The stakes are too high to continue to accept the status quo. Just as in the past, the major transportation system investments and private sector land-development activities occurring today will become fixtures in the landscape and economy of the nation. Better information and better methods are needed to support intelligent policy and investment decisions in the near term, as well as the long term. Failure to improve our knowledge and policies may result in significant and long-lasting damage to our nation's human, economic, and environmental well being. Investment in research and its implementation offers real promise for improved performance of our transportation systems.

CONCLUSIONS

The 2002 NRC–TRB Advisory Board articulated the need for a well-funded, coordinated environmental research agenda. The United States has been a leader in vehicle and fuel technology, highway system development, and carpooling and vanpooling innovations, but it lags behind in other important ways, and continues to fall short of creating an environmentally sound transportation system.

The transportation community must become more engaged in working through metropolitan planning organizations, the elected officials serving on their boards, and the many related groups concerned with pollution, environmental justice, energy use, land consumption, and social community with related interests. Sustainable transportation, in all its dimensions, has remained a national policy issue and recently emerged as a global issue. Unfortunately, the planning and development community as well as transportation planning research has not adequately engaged questions of “sustainability.” This workshop offers a unique opportunity to link researchers and practitioners in an endeavor to forge a U.S. agenda that will focus research,

realign practice, and position institutions to become major players in critical transportation issues of the new millennium.

RESEARCH NEEDS STATEMENTS

Sustainability, Including Climate Change: Cause and Effects

1. What Is the Responsibility of the Surface Transportation Sector for Sustainability?

Problem Statement

Although much is known about the effects of surface transportation on greenhouse gas emissions and climate changes, much less information is available upon which to measure its impact on other indices of sustainability. Some would argue that there is little agreement as to the appropriate measures or definitions of sustainability itself. However, the idea of sustainability is increasingly coming to be understood as a collective process for considered decision making and action and not simply a particular end-state or outcome. There is a growing consensus that sustainability must include economic betterment and social equity, not just a narrow technical focus on greenhouse gases or other aspects of the natural and human environment.

Transportation professionals are being asked to implement projects and programs that are responsive to issues and policies outside their normal realm and that may serve multiple policy objectives under the banner of sustainability. Research is needed to help transportation officials and policymakers better understand the connection between the surface transportation system and public policy goals that extend beyond motorist safety, air quality, traffic flow, and environmental protection.

Proposed Research

As a first step towards developing this better understanding, research is necessary to document examples of sustainable development initiatives that have incorporated transportation projects and programs, both in the United States and within the international community. This review would provide a broad overview of the ways in which transportation is being used as a tool to achieve more sustainable communities and should focus on identifying

- Measures and indices of sustainability that incorporate transportation, and
- Transportation projects and programs that have been adopted in response to policies aimed at achieving sustainable development.

As a second step, U.S. best practices will be presented as case studies. The case studies will identify common elements among successes, pitfalls to avoid, and detailed evaluations. Examples of case studies may include:

Maryland Smart Growth—The state of Maryland implemented a comprehensive smart growth program in 1997 designed to ensure that state resources were focused in planned growth areas. It is seen as a model program in the United States, but its effectiveness has not been evaluated.

New York Quality Communities Program—The state of New York has developed a Quality Communities initiative to encourage infill development and urban renewal within its cities and

towns. Although comprehensive in scope, the program has not been evaluated for its environmental or preservation benefits.

Cost: $300,000
Duration: 18 months

2. Implications of Climate Changes on Infrastructure: Transport and Potential Adaptations to Climate Changes

Problem Statement
A growing body of research is documenting the possible effects of climate changes on the United States and the world. A National Assessment conducted by the U.S. Global Change Research Program, *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change,* discusses a range of potential impacts including changes in temperature, shifts in precipitation rates, the increasing frequency and severity of storms, and melting permafrost. The national assessment process has so far included 17 regional assessments that examine the potential effects of climate changes on various regions of the country, as well as five sectoral assessments. Although changes in climate, water levels, storm activity, and other effects will each have important implications for transportation infrastructure and operations, little research has yet been conducted to explore these effects, which vary by location. There are numerous studies that could be conducted to examine potential impacts on transportation and possible adaptation strategies to avoid or minimize these effects.

Proposed Research
The proposed research would examine the potential effects of climate changes on transportation networks, drawing from the scenarios developed by the U.S. Global Change Research Program's National Assessment, the Intergovernmental Panel on Climate Change, and other scientific research. The research would be conducted as a series of case studies. Each case study would focus on a different region of the United States (e.g., Great Lakes, southeastern coast, Alaska) and/or the effects on a particular mode or service component of the nation's transportation system (e.g., flooding of critical highway and transit facilities, potentially reduced aviation safety and reliability, pavement durability, and marine freight). The studies would include a review of the potential climate changes, and the probability of these changes, based on available science. The impact of these potential climate changes on the transportation element will be assessed. The case studies will include

- An analysis of the implications of the climate changes on the transportation elements in the region/mode under discussion, including an analysis of the associated risks and costs.
- A discussion of potential adaptation strategies that could be considered by transportation agencies and regional planners.
- An examination of how potential adaptation strategies and redesign could be accomplished consistent with other environmental goals.

Cost: $200,000 per case study
Duration: 12 months per case study

3. STRATEGIES FOR GREENHOUSE GAS REDUCTION

Problem Statement

Human activity is generating increasing amounts of carbon dioxide and other greenhouse gases (GHGs), with possible evidence that this buildup is altering climate. Considerable effort is being devoted to understanding the relationship between GHG emissions and climate change, but relatively little to the relationship between transportation and GHG emissions, especially in the United States. Europe and Japan are ahead in developing an understanding of the nature of the contributions of their transportation systems to the potential global warming phenomena and of the potential strategies that are available or that could be developed to lessen GHG emissions. Strategies may be grouped into those targeted at transportation technology, fuels, travel behavior, and land use. The strategies that are most effective are those that include a mix of policies and initiatives. The mix and specifics of the actions taken will vary considerably from one region to another, depending on local institutions, resources, economic activities, and cultures.

A two-phase program is proposed: The first phase provides an overall framework and the second is an analysis of cross-cutting strategies.

Phase One: Overall Framework

Proposed Research

The first step in phase one is to document what is known about the contribution of different components of the transport sector to climate change, as disaggregated as possible. Then a framework should be developed to specify the amount of reduction possible in different activities and with different initiatives. This framework would reflect what is known about demand elasticities, technological progress, and the linkage of GHG reduction strategies with other social goals (including pollution reduction, petroleum import reduction, public financing constraints, public health, and urban livability). This framework should identify opportunities for action at the local, state, and federal level.

Cost: $200,000
Duration: 12 months

Phase Two: Analysis of Cross-Cutting Strategies for Green House Gas Reduction

Virtually all effective GHG reduction strategies include technology, behavioral, and institutional elements. Research is needed that considers synergies, interrelationships, and indirect impacts and benefits. Under the direction of a single program manager, four separate research projects are to be conducted.

3. 1. Vehicle Technology and Fuels

Problem Statement Alternatives to petroleum fuels and internal combustion engines are becoming more compelling. Imported fuels now account for more than one-half of all consumption, and approximately two-thirds of this petroleum is used for transportation. Motor vehicles, using internal combustion engines, operate almost exclusively on petroleum fuels (approximately 97% dependent), contribute about one-half the air pollution in urban areas, and

account for more than one-fifth of all GHGs emitted in the United States. With calls for more environmentally benign vehicles and fuels intensifying, and rapid innovation in propulsion technologies, major changes are about to happen. Better understanding is needed of the choices and pathways of change. An improved knowledge of these technologies and their impacts would inform the policy process with respect to pollution, energy use, energy choices, and climate change. Government and the public should seek to be well informed to ensure that environmental factors are adequately considered in the development, evolution, and use of these products. The challenge is to complement and not duplicate industrial research and development.

Proposed Research Knowledge is needed to inform public strategies for diesel engines, hydrogen fuel, fuel cells, and a variety of other options. For example, diesel fuels and engines have higher emissions of nitrogen oxides and particulate matter than gasoline combustion, but substantially lower GHG emissions and energy consumption. How large are these effects? Likewise, hydrogen and fuel cells are widely seen as the dominant fuel and vehicle propulsion technology of the future, partially because of their superior environmental attributes. Better understandings are needed of the costs and benefits, the role of public policy in developing new fuel distribution systems, and the role of public policy in aiding the transition to environmentally beneficial fuels and vehicles.

Because of the especially broad cross-cutting nature of a hydrogen path, it is recommended that special attention be given to hydrogen. Energy systems of the future will likely use hydrogen and electricity as the energy carriers, probably integrated into a single system. The implications are broad and cut across many industries and activities. The implications for the transport sector are huge—for fuel distribution, vehicle design and use, fuel and vehicle supplier industries, vehicle maintenance, and vehicle attributes. Eventually, it is expected that vehicles would be powered by fuel cells that operate on hydrogen, and likely integrated into stationary energy systems. Such a system, transitioning eventually to hydrogen made from solar and other renewable sources, would essentially eliminate emissions of air pollutants and GHGs, and reduce international tensions that result from competition for limited petroleum supplies. However, the transition path to a hydrogen economy is unclear. Many different paths may be followed, with different economic, environmental, social, and political implications. Substantial research is already underway in the private sector—on developing better fuel cells for vehicles and electricity production, better hydrogen storage containers, and better hydrogen production processes. Ongoing public research is needed to guide public investments in research and development, support basic research (industry under-invests in these technologies and fuels because a large share of the benefits are market externalities), investigate environmental benefits and costs, inform policies addressing fuel and vehicle safety, air pollution, GHGs, and energy dependence. Research is also needed to anticipate issues associated with the integration of mobile and stationary energy production (e.g., connecting fuel cell vehicles into the electricity grid) and the development of hydrogen fuel distribution systems that might be linked with electricity supply systems.

Cost: $300,000
Duration: 24 months

3.2. Demand Management Strategies for Greenhouse Gas Reduction and Sustainability

Problem Statement For several decades, growth in vehicle miles of travel (VMT) has exceeded growth in both the number of households and population, and most forecasts assume that this upward trend will continue unless public policy intervenes. Demand management is one strategy for reducing VMT growth and therefore GHG emissions (and related problems of congestion and air pollutant emissions). Demand management strategies promote the use of alternative modes or reduce the number or length of trips, thus reducing VMT. Specific strategies include the promotion of transit, ridesharing, biking, and walking, as well as telecommuting, teleconferencing, teleshopping, and pricing strategies. Demand management strategies would be linked with initiatives that introduce new vehicle and fuel technologies, new intelligent transportation technologies, new mobility services, and land use management and planning. Although travel alternatives and trip reduction strategies have been widely implemented, few studies have explicitly considered their impact on GHG emissions and broader sustainability efforts. Some modes have not received as much attention as others. For example, bicycling and walking are quiet, efficient, nonpolluting, healthy, economical, and desirable, yet planning for bicycling and walking is often limited by a lack of data. Also, because the use of these modes is fundamentally local in nature, integration of biking and walking strategies into regional plans, programs, and budgets remains problematic in many areas. Furthermore, pricing is a fundamental element of any technology strategy and is just beginning to be applied as an explicit demand management strategy. There are few detailed and comprehensive analyses of its impacts.

Proposed Research This research study will be threefold:

1. Inventory the full range of demand management strategies that have been implemented, with particular attention to nonmotorized modes and new transportation technologies. Document each strategy's impacts, considering in particular its effects on emissions of GHG and other sustainability metrics. Also, prepare an inventory of the pricing strategies that have been proposed, including congestion pricing, toll pricing of road use, variabilization of motor vehicle costs, parking pricing, paying at the pump, insurance, fuel tax increases to include externality costs, emissions charges, carbon taxes, and other pricing strategies identified by the researchers. Document social, economic, and environmental costs and benefits associated with each pricing strategy and implementation experiences if any, paying particular attention to differences in context and their consequences.
2. Prepare case studies of the implementation of major demand management programs at the state, regional, or local levels and document their effects on mobility, energy use, and environmental quality. Investigate and document the incidence of these impacts by income, race/ethnicity, sex, and geographic area (e.g., central city, and suburbs). Cases should include an explicit focus on modes and strategies that appear to offer the most promise for GHG reduction and improved sustainability.
3. Investigate and document institutional, political, and other factors that appear to have fostered implementation of demand management strategies where they have occurred. Identify key planning practices and legal and regulatory frameworks, as well as the role of leadership, public education, public involvement, etc., in fostering the implementation of demand management strategies. Also, investigate and document factors that have

served as barriers to demand management. Recommend strategies for overcoming barriers, recognizing the variety of local circumstances extant in the United States.

Cost: $100,000
Duration: 24 months

3.3. Integrated Transportation/Land use: Environmental Strategies for Sustainability
Several states and metropolitan regions have implemented programs that combine land use, transportation, and environmental policies into integrated plans and programs. Examples include the state of Oregon's state and regional planning requirements, implemented and refined over the past three decades; the state of Maryland's smart growth program, implemented in 1997; and Atlanta Georgia's Regional Transportation Authority. European Union nations also are beginning to implement similarly integrated programs, as documented in the European Conference of Ministers of Transport final report, *Implementing Sustainable Urban Travel Policies.* These new programs have been in place or under way for several years, long enough that an evaluation of their efficacy is timely. The proposed research would document and evaluate these new initiatives. The evaluation would be designed to help decision makers and practitioners understand what land use policies, planning processes, and combinations of environmental policies and plans and transportation demand management, capital investment, and technological innovation are effective, as well as those that do not work well. It would also be forward looking in examining the planning efforts for incorporating transportation innovations, including new types of vehicles and mobility services, such as smart car sharing and smart paratransit, dynamic ridesharing, and neighborhood vehicles.

Proposed Research This study will identify and document integrated transportation and land use environmental technology plans and programs in the United States and other developed countries. Specific measures that are included in the plans and programs will be identified and evaluated, considering their implementation status as well as their social, economic, and environmental performance. Specific land use, transportation, and environmental measures and combinations of measures that have proven effective in various implementation contexts will be identified, along with the processes through which they have been implemented. Measures that have been less successful also will be noted, together with the apparent reasons for lower-than-anticipated performance.

Cost: $150,000
Duration: 12 months

3.4. Intelligent Transportation System Technologies for Sustainability

Problem Statement Intelligent transportation system **(**ITS) technologies offer numerous opportunities for increasing transportation sustainability that have not been fully identified and evaluated. For example, state departments of transportation are using ITS to increase safety and improve traffic flow through better traveler information about road conditions and faster removal of disabled vehicles and other road obstacles. Transit operators are using ITS to manage operations and provide better information to transit users. ITS technology applications are beginning to be extended to provide environmental monitoring—for example, monitoring the

transport of hazardous wastes. ITS applications also suggest ways to improve the efficiency of the transportation system; for example, by using smart card applications for time-of-day pricing. Additional research could identify a wider range of potential applications of ITS for reducing environmental impact and increasing sustainability. This research could also identify the longer-term effects of ITS on urban systems and their performance.

Proposed Research This research would evaluate ITS technologies' social, economic, and environmental impacts and identify opportunities for using ITS technologies to improve overall sustainability. The research would identify both near- and long-term ITS technologies. For example, ITS technologies could facilitate shared modes of transportation (such as "on-the-fly" car pooling), use stored-value media to permit variable pricing and manage subsidies and other transfer payments, manage parking and provide better traveler information on its availability and location, coordinate transportation information for multiple modes through an automated "mobility management" system, and increase pedestrian and bike safety. ITS technologies also could be applied to identify gross polluters, monitor and enforce speeds, and otherwise regulate transportation systems for safety and environmental performance. The research will identify new strategies for applying ITS technologies to improve sustainability.

Cost: $200,000
Duration: 12 months

4. Reform of Policy Instruments to Encourage Sustainability and Climate-Friendly Policies

Problem Statement
Current public policies and the mechanisms that implement them reflect the environmental, political, economic, and technological circumstances of past and current experience. The advent of new system-transforming technologies may necessitate a redesign of many of these policies and policy instruments. New challenges such as global warming also may call for a major overhaul of today's policy instruments in consideration of reducing emissions and fuel consumption. This may include shifting away from petroleum fuels and internal combustion engines, reducing VMT, increasing emphasis on particulate matter and possible climate change threats, and making greater use of market instruments (including travel demand management and VMT-reducing measures). Consider the following examples:

- Road financing is premised on vehicles consuming petroleum fuels roughly in proportion to their use.
- Emissions and fuel economy standards are premised on the use of internal combustion engines and petroleum fuels.
- Vehicle regulation and many types of enforcement of traffic and parking rules have been based on the presumption that the driver of a personal vehicle owns the vehicle.
- Rules limiting jitney services are premised on the ubiquity and effectiveness of conventional bus and rail services.

Proposed Research

This project will identify need and opportunities for policy reform and will identify policy instruments that can be used to help government agencies and actors manage and take full advantage of changing technologies, as well as respond effectively to possible new environmental challenges such as global warming. The study will address such questions as

- How and at what levels of government might emissions trading be employed to reduce GHGs?
- What is the role of voluntary programs for emissions reductions?
- What are the implications for public policy of moving toward a vehicle fleet that operate on non-petroleum fuels?
- What policy instruments can be devised that allow for trade-offs between different goals (such as diesel's lower GHG emissions, but higher particulate emissions)?
- What are the regulatory issues associated with a growth in car sharing?
- Would new forms of "smart paratransit" suggest a rethinking of regulations on transit, taxis, and other forms of transportation?
- What policies and programs are needed for pricing and other demand management strategies to be applied most effectively?

The project will include a conference based on results from a field survey of both transportation and environmental professionals. The resulting report will include a discussion of best practices in the field of transportation and sustainability. The report will present 3 to 5 (or more depending on developments) best practices and a "how-to" guide for implementation purposes.

Cost: $175,000
Duration: 12–18 months

5. INSTITUTIONAL ARRANGEMENTS AND PLANNING PROCESSES FOR SUSTAINABILITY

Problem Statement
Decision-making institutions must be capable of meeting the challenges posed by global climate change and sustainability issues. This requires capacity building at both the policy and technical levels of transportation agencies, planning organizations, and state and local governments. It also requires exploration of the barriers to effective coordination between transportation decisions and land development. Research is needed to identify the institutional arrangements and policy structures that have the capacity, authority, and public support needed to effectively carry out sustainable transportation planning and project development.

Proposed Research

Part I: Institutional Arrangements and Planning Processes for Sustainable Transportation
This research would identify institutional arrangements and planning processes that effectively support integrated, performance-based planning and decision making. Specific topics to be addressed include organizational arrangements and assignments of responsibility, methods, and processes for

1. Better integrating transportation, land use, and environmental planning and programming, and for considering both capital and noncapital strategies for mobility improvement;
2. Communicating the results of sophisticated technical analyses and performance comparisons to decision makers and the public;
3. Incorporating customer needs, preferences, and viewpoints into the decision-making process;
4. Better coordinating land use and environmental decision making across disparate agencies and programs; and
5. Dispute resolution.

The research will focus as much or more on institutions as on techniques. It will also examine the contribution of institutional barriers to the current lack of integration of planning functions and suggest structural changes that can eliminate the most significant barriers.

Cost: $150,000
Duration: 18 months

Part II: Transportation Finance
Transportation decision making is strongly influenced by the sources and amounts of funding available for various activities and for the mandates and limitations imposed on the use of funds. The implementation of sustainable transportation strategies may alter existing petroleum-based revenue streams and could also provide new revenue sources. This project will evaluate how various transportation strategies being proposed for GHG reduction and sustainable development are likely to affect transportation revenue streams. For example, petroleum-based taxes will decline as electric and other alternative-fueled vehicles penetrate the market; strategies that dampen travel growth and increase vehicle fuel efficiency may reduce per capita revenues based on fuel consumption. Pricing strategies, on the other hand, would generate new revenues, and how the revenues are directed will have implications for mobility as well as for environmental and economic performance. The project also will identify alternate strategies for providing adequate funding for a sustainable transportation future. For each strategy, efficiency, equity, and political acceptability will be evaluated.

Cost: $150,000
Duration: 18 months

6. Forecasting and Analytic Tools to Support State and Local Global Warming Studies

Problem Statement
Transportation organizations in the United States have not had the opportunity to study their current and planned transportation systems, including vehicles and fuels, to examine the degree to which they contribute to climate change. Although the issue is on the minds of many officials, few modeling tools have been made available for climate change analysis. A modeling structure does exist for transportation planning and air quality analysis. It is widely used and supports planning for highway and transit systems and for air quality conformity analysis. Models also

are widely used for traffic operations analyses. These models could be enhanced to produce estimates of GHG emissions.

Proposed Research
This project will review the most commonly used models and identify those that could be enhanced in a cost-effective manner to produce information about GHGs. The core transportation models would not be entirely rewritten, but additional routines might be added or, alternatively, post-processors could be provided to calculate GHG emissions from the vehicles moving on the transportation systems. The models will also be reviewed and recommendations will be made on other modifications to the software to more broadly include benchmarks and sustainability measures (to be addressed in a separate effort.)

These models can then be made available to states and metropolitan planning organizations that want to undertake studies to help understand global climate change consequences of existing transportation systems and proposed changes to them.

Cost: $150,000
Duration: 12 months

7. BENCHMARKING TRANSPORTATION FOR SUSTAINABILITY
Benchmarking is "the process of identifying, understanding, and adapting outstanding practices from organizations anywhere in the world to help your organization improve its performance."

Problem Statement
In the realm of transportation system performance, one of the greatest demands from both within and outside the transportation planning community is for assessment of the sustainability of alternative transportation and land use plans. There is a need for methods and tools that can be used to test alternative visions and public policies against the ability of a metropolitan area or community to maintain its systems over time. Research regarding the impacts of transportation policy and investments on environmental protection and enhancement, energy consumption, land consumption, economic health, and affordability must be translated into tools available for use at the front lines of transportation decision making. The need for this particular facet of performance measurement is compounded by the fact that the United States will have to accommodate the activities of tens of millions of additional residents in the coming years. Metropolitan areas such as Atlanta, Georgia, and Dallas–Fort Worth, Texas, continue to absorb population growth in excess of 10,000 residents per month. These rapidly growing areas have a tremendous need for tools that can be used to assess the long-term sustainability of current practices.

Proposed Research
Research is necessary to identify a range of potential benchmarks that will provide transportation planners with the indicators they need to evaluate progress towards new policy goals. The indicators should also enable comparison between jurisdictions. The research would

- Review the current state of the practice in benchmarking techniques and approaches, both in the United States and abroad, particularly in relation to transportation and sustainability.

- Identify common measures (both existing and needed) and indicators of sustainability for use by all levels of government.
- Identify the data needs necessary to support the use of such indicators.
- Initiate a process by which selected urban areas and states would compare their development and use of benchmarks.

Cost: $600,000
Duration: 24 months

8. TRAVELER ATTITUDES AND BEHAVIOR TOWARD SUSTAINABLE TRANSPORTATION

Problem Statement
Unlike most other countries, travelers in the United States rely on motor vehicles for virtually all local and regional travel. Moreover, the vehicle population of the United States tends to be rather homogeneous relative to other countries. Very few small vehicles are used and almost all vehicles operate on gasoline and diesel fuel. With the proliferation of vehicles (more than one per licensed driver), the availability of low-cost wireless and information technologies, and the introduction of new fuels and propulsion technologies, the opportunities arise to better serve travelers. Traveler desires can be met at lower cost, with higher quality service, and/or lower environmental impact. Currently in the United States, most travelers do not reflect on their choice of mode with the advent of new technologies and a growing awareness of the health and livability cost associated with high dependence on car travel; therefore, it is time to better understand traveler behavior. However, little information currently exists about the public's willingness to accept likely attributes of these new transportation technologies (such as home recharging of electric vehicles, the safety aspects of new fuels, or the use of smaller vehicles in various settings.) Research is needed on traveler attitudes and behavior in the context of the broader set of transportation choices becoming available to consumers. Research also is needed on ways to provide the public with information about travel choices and to educate them about the consequences of their choices.

Proposed Research
The proposed research will investigate traveler attitudes and behavior to better understand the conditions and circumstances under which travelers would make more sustainable transportation choices; that is, choose to walk or bike, use car sharing and other "smart" mobility services (e.g., dynamic ride sharing), buy and use environmentally beneficial vehicles and fuels (fuel cell vehicles, small battery electric vehicles), or reduce travel through telecommunications substitutes. The research also will examine ways in which new transportation technologies could be introduced to the marketplace, including the identification of possible new market segments for innovative transportation options. Roles for and effects of marketing and public education, especially with regard to "new" vehicle attributes and transport services unfamiliar to consumers, will be examined. Finally, the possibility that new transportation choices could lead to significantly different activity patterns and work styles will be considered in assessing the implications for travel, vehicle choice, energy use, and the environment.

Cost: $200,000
Duration: 24 months

9. SUSTAINABILITY ANALYSIS PILOT PROGRAM FOR STATE AND LOCAL GOVERNMENTS

Problem Statement
GHG emissions and other sustainability issues are of concern to federal, state, and local governments. Policy debates increasingly involve the question, What are you doing about the possibility of global warming? Or more specifically, transportation officials are asked; Are your investments sustainable? Although the federal government has been involved in global warming discussions for many years, very few opportunities have existed for state and local transportation officials to evaluate their infrastructure and the vehicles on them to consider the sustainability implications of current policies and practices and the potential implications of project and program proposals. There is an urgent need for state and local officials to better understand the sustainability characteristics of their systems if they are to be informed participants in the discussions/debates that will lead to the development of national policies. It would be extremely costly if all state and local governments were to undertake such analyses, especially since at the present time there are no well-established approaches for such studies. A pilot program can serve to develop methods and procedures and to establish the feasibility and desirability of sustainability analysis.

Proposed Research
This project will establish a grant program to allow three states and three metropolitan planning organizations (MPOs) to undertake pilot sustainability research projects to permit them to understand the degree to which their current and proposed transportation systems are sustainable under criteria they will establish. Computer software will be provided to allow the selected recipients to undertake a GHG emissions analysis of their existing systems. The projects will then look at the various policies or policy packages that will be necessary to allow them to meet their sustainability criteria.

Cost: $600,000 ($100,000 each to three state departments of transportation and three MPOs)
Duration: 24 months

10. FREIGHT TRANSPORTATION AND SUSTAINABILITY

Problem Statement
Sustainability, in the broader view, is comprised of economic, environmental, and social components. Economic stability and growth is partially dependent on the successful movement of freight. Truck usage alone has grown and now accounts for more than 90% of all shipments. Also, since 1970 truck travel has more than tripled, with the number of heavy combination trucks nearly quadrupling. Combined with the movement of people, freight movement can have a profound impact on achieving sustainability, including climate change. There is a need for a national, state, and local information system developed for state and MPO planners to facilitate the introduction and evaluation of innovative major infrastructure improvements and investments to promote intermodal coordination and to enhance the efficiency of goods movement. The result should be an increase in economic efficiency and performance while reducing energy use as well as GHGs and conventional emissions leading to sustainability.

Proposed Research
A better understanding of the future movement of freight is needed to influence a sustainable approach to freight transport. To achieve an understanding of freight movement, research is needed that will identify the sustainability characteristics of freight transport. Furthermore, there is a need for a local, state, and national information system developed to facilitate the introduction and evaluation of innovative infrastructure improvements and investments to promote intermodal coordination and to enhance the efficiency of freight movement leading to sustainability. Sustainable alternatives will need to consider energy efficiency that will likely require novel and innovative research initiatives for freight systems and major infrastructure investments (i.e., maglev) by government and the transport industry.

Cost: $175,000
Duration: 12 months

11. ECOSYSTEM IMPACTS: INTEGRATED PLANNING STRATEGIES AND ASSESSMENT METHODS

Problem Statement
A 4-million-mile public road network carrying 230 million vehicles covers approximately 1% of the United States—equal to the size of South Carolina. A recent article published in *Conservation Biology* presenting the first calculation of the ecological effects of this road system suggests that roughly one-fifth of the total U.S. land surface is directly affected. The current road network was essentially built prior to the first Earth Day in 1970, long before the explosion in environmental knowledge represented by modern ecology. The Transportation Research Board report, *Toward a Sustainable Transportation Future,* identifies ecosystem impacts as a key sustainability issue.

Landscape ecology is a rapidly developing body of knowledge and research that represents a relatively new, highly useful, and far-reaching dimension for consideration in transportation planning and activity. Landscape ecology (including the related areas of conservation biology and watershed science) provides principles and models that directly address issues such as habitat fragmentation; arrangements of green patches; wildlife corridors for foraging, dispersal, and migration; and groundwater and surface-water flow paths, all of which can be related to transportation networks. Integrating transportation systems with these principles, processes, and models is a key collaborative opportunity for engineers, ecologists, and planners. The results of such collaboration should have notable application in transportation planning, evaluation of transportation projects, and overall environmental stewardship. They also should establish an important approach for addressing sustainability issues.

Proposed Research
The recommended research builds on strong foundations in transportation research in such areas as hydrology, sediment flow, roadside vegetation management, roadkill, traffic flows, and pollutant emissions, all factors that are critical to environmental sustainability. The research will develop a methodology to integrate transportation systems planning and ecosystems planning. At the planning and ecosystem level opportunities exist to approach problems on a broad basis, where the greatest number of options for solution exist. For example, wildlife movements over large habitat areas can be studied to determine the most cost-effective ways of avoiding habitat fragmentation. The research will also identify ways transportation agencies can integrate

ecosystem considerations into planning design, construction, and management. This integrated approach should identify opportunities to develop more ecosystem-friendly new projects, as well as identify appropriate maintenance and reconstruction policies and practices, including opportunities to mitigate situations where existing projects fragment habitat, impede migration, or obstruct fish spawning routes. Lastly, the project will identify ways to better integrate wildlife and plant resource considerations in the National Environmental Policy Act of 1969 (NEPA) process. Ecosystem approaches should help develop more meaningful treatment of species of flora and fauna than the often-seen project area-limited-species list approach observed in many Environmental Impact Statements. Ecosystem consideration should facilitate the dialogue between transportation agency and resource agency staff and create opportunities to break away from "compliance" debates toward positive discussions on how to create win–win situations for transportation and wildlife, resulting in a more sustainable transportation system.

Cost: $200,000
Duration: 24 months

12. Cumulative, Areawide, and Indirect Impacts of Transportation

Problem Statement
Most roads, railroads, ports, airports, and transportation support infrastructure were built prior to mainstream environmental analysis and assessment. The numbers of vehicles, boats, and miles traveled on these facilities continue to increase. One result is a variety of adverse impacts on the human and natural environments: air pollution, traffic noise, water pollution, congestion, neighborhood disruption, habitat fragmentation, invasive species, disposal and recycling concerns, and climate change. Although impact assessment has traditionally been project-related, there is growing understanding that cumulative, areawide, and indirect impacts and their interactions are highly significant and are an indicator of overall sustainability. Better methods for addressing cumulative and areawide impacts must be integrated into transportation planning and evaluation practices if we are to effectively increase the sustainability of the transportation system. Planning and design approaches are needed that would protect and enhance human and natural environments, as well as reestablish healthy conditions in areas that currently are adversely affected by transportation, if we are to achieve a sustainable transportation system.

Proposed Research
This project will identify best practices for addressing the cumulative and areawide impacts of transportation including, when possible, the quantification of these impacts. The research also will examine and recommend ways to go beyond the current limited focus of individual transportation projects so that consideration is given to corridor, regional, and systems effects of transportation. The identified practices should allow project proponents to better understand and quantify the cumulative effects of their actions on sustainability. Planning and project development approaches will be recommended that emphasize environmental stewardship and incorporate environmental considerations into project design, rather than focus on simply mitigation. The results could also have utility applied in the NEPA environmental assessment process.

Cost: $300,000

Duration: 24 months

Collaborative Research Needs Statements

13. ANALYZING THE SUSTAINABILITY OF VARIOUS ALTERNATIVE FUELS AND ADVANCED TECHNOLOGY VEHICLES IN SELECTED NICHE VEHICLE MARKETS

For full text, see Section 2 under Energy and Alternative Fuels

14. POTENTIAL TRAVEL RESPONSES TO ALTERNATIVE HIGHWAY PRICING AND FINANCING SYSTEMS AND THE IMPACT ON FUEL CONSUMPTION AND GREENHOUSE GAS EMISSIONS

For full text, see Section 3 under Energy and Alternative Fuels.

15. FUEL ECONOMY AND GLOBAL WARMING: UNDERSTANDING CONSUMER BEHAVIOR AND THE INCREASING AWARENESS OF LINK THE BETWEEN FUEL CONSUMPTION AND GLOBAL WARMING

For full text, see Section 7 under Energy and Alternative Fuels

16 PREPARE A COMPENDIUM OF SUSTAINABLE DESIGN IDEAS FOR USE BY A WIDE RANGE OF TRANSPORTATION SEGMENTS

For full text, see Section 5 under Waste Management and Environmental Management: Recycling, Waste Reduction, Pollution Prevention, Brownfields

17. CREATE A METHODOLOGY TO INTEGRATE SUSTAINABLE DESIGN CONCEPTS INTO TRANSPORTATION PROJECTS AND INFRASTRUCTURE

For full text, see Section 6 under Waste Management and Environmental Management: Recycling, Waste Reduction, Pollution Prevention, Brownfields.