



HIGHWAY
RESEARCH
AND
TECHNOLOGY

*The Need for
Greater Investment*

A Report of the
NATIONAL HIGHWAY R&T PARTNERSHIP
APRIL 2002

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Preface

The National Highway R&T Partnership was initiated by the Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), and Transportation Research Board (TRB). The purpose is to provide an opportunity for the entire highway community to be engaged in the identification of research and technology (R&T) needs. This report is the product of that initiative, which was unprecedented in terms of outreach—hundreds of individuals and more than 170 organizations participated.

The partnership has no official standing; rather, it operates as an ad hoc group sharing a common interest in ensuring that R&T programs serve the needs of the highway community and the public. All participants have acted in a volunteer capacity, working together in a cooperative effort to bring R&T needs to the attention of funding agencies. Because of the ad hoc nature of the partnership's activity, it should be noted that there is no implied endorsement or adoption of this report by any of the participating organizations identified in the following list. Representatives from the agencies identified in the list participated in the meetings of the full forum, or in the activities of the working groups created within the partnership to identify R&T needs, or in both.

This report is being provided to potential sponsors of the R&T needs identified herein for their consideration in developing programs. Sponsors should recognize that the working groups operated independently, and areas of overlap and omission have not been fully addressed. Future activities of the partnership will be determined in mid-2002.

PARTICIPATING ORGANIZATIONS

Federal Agencies

Administration on Aging	U.S. Army Cold Regions Research and Engineering Laboratory
Bureau of Economic Development	U.S. Army Corps of Engineers
Bureau of Transportation Statistics	U.S. Army Waterways Experiment Station
Federal Highway Administration	U.S. Department of Energy
Federal Motor Carrier Safety Administration	U.S. Department of Housing and Urban Development
Federal Transit Administration	U.S. Department of Transportation (Office of the Secretary/the Volpe Center)
National Highway Traffic Safety Administration	U.S. Environmental Protection Agency
Research and Special Programs Administration	U.S. Forest Service

State Departments of Transportation

Arizona	Mississippi
Arkansas	Missouri
California	New York
Colorado	North Carolina
Connecticut	Oklahoma
Florida	Oregon
Illinois	Pennsylvania
Iowa	South Dakota
Kansas	Texas
Maryland	Utah
Michigan	Virginia
Minnesota	West Virginia

Associations, Foundations, and Institutes

AAA Foundation for Traffic Safety	Civil Engineering Research Foundation
American Association of Retired Persons	Connecticut Transportation Institute
American Association of State Highway and Transportation Officials	ENO Transportation Foundation
Special Committee on Economic Expansion and Development	Environmental Law Institute
Standing Committee on the Environment	Head Protection Research Laboratory
Standing Committee on Highway Traffic Safety	HITEC
Standing Committee on Highways	Innovative Pavement Research Foundation
Subcommittees on Bridges and Structures, Construction, Design, Materials, Highway Transport, and Traffic Engineering and Joint Task Force on Pavements	Institute of Transportation Engineers
Standing Committee on Planning	Intermodal Association of North America
Standing Committee on Research	ITS America
Research Advisory Committee	Market Development Alliance of the FRP Composites Industry
American Automobile Association	National Asphalt Pavement Association
American Concrete Pavement Association	National Association of County Engineers
American Petroleum Institute	National Association of Governors' Highway Safety Representatives
American Public Transportation Association	National Association of Regional Councils
American Public Works Association	National Center for Asphalt Technology
American Road and Transportation Builders Association	National Lime Association
American Traffic Services Association	National Resources Defense Council
Applied Technology Council	National Society of Professional Engineers
Association of American Railroads	National Steel Bridge Alliance
Association of Metropolitan Planning Organizations	National Stone Association
ATA Foundation (American Trucking Associations)	Portland Cement Association
	Roadway Safety Foundation
	Rubber Pavements Association
	The Asphalt Institute
	The Urban Land Institute
	Truck Maintenance Council
	Virginia Tech Transportation Initiative
	Virginia Transportation Research Council
	Water Resources Center
	W.E. Upjohn Institute for Employment Research

Consultants and Industry

Alan E. Pisarski	Michael Finkelstein & Associates
Baker Engineers	Mitretek Systems
Cambridge Systematics	Motion Maps, LLC
Carlton C. Robinson	Nationwide Insurance
CH2M HILL	Nichols Consulting Engineers
Construction Technology Laboratories, Inc.	Oldcastle Materials
Consulpav International	Parsons Brinckerhoff
David Keever	State Farm Insurance Company
EvTEC	TDC Partners
Francis B. Francois	Technologic Resources, Inc.
Furgo-BRE	Thomas Larson
Gardner Systems	Traffic Safety Software, LLC
Granite Construction	TRDI
HNTB Corporation	T.Y. Lin International
Koch Materials Company	Vernon J. Marks
Koch Pavement Solutions	WEFA, Inc.

Universities

Arizona State University	University of California (Institute of Transportation Studies)
Auburn University	University of California, Riverside
Central Missouri State University (Missouri Safety Center)	University of Florida
Florida International University	University of Iowa
George Mason University	University of Maine
Georgia Institute of Technology	University of Maryland
Harvard University (John F. Kennedy School of Government)	University of Massachusetts
Iowa State University	University of Michigan
Louisiana State University (Louisiana Transportation Research Center)	University of Minnesota
Massachusetts Institute of Technology	University of Missouri-Rolla
Morgan State University	University of Nevada-Reno
North Dakota State University (Upper Great Plains Transportation Institute)	University of New Mexico
Pennsylvania State University	University of North Carolina (Highway Safety Research Center)
Polytechnic University of New York	University of Southern California
Rensselaer Polytechnic Institute	University of Texas at Austin
Texas A&M University (Texas Transportation Institute)	University of Virginia
University of California, Berkeley	University of Wyoming
	Virginia Polytechnic Institute and State University
	Wayne State University
	West Virginia University

Other Organizations

Center for Neighborhood Technology	Norfolk Transportation Department
Construction Industry Roundtable	Rails-to-Trails Conservancy
Council of University Transportation Centers	Siskiyou County Public Works Department
East-West Gateway (St. Louis)	STAPPA/ALAPCO
General Motors Corporation	Surface Transportation Policy Project
Metropolitan Washington Council of Governments	The World Bank Group
National Cooperative Highway Research Program	Transportation Research Board
NOISE	United Auto Workers
	U.S. Conference of Mayors

Acknowledgments

The work of hundreds of individuals and more than 170 organizations contributed to the development of this report. Because the partnership is a volunteer initiative, each individual's contribution deserves recognition. The names of most participants are included in the working group reports, which can be found on the Transportation Research Board's (TRB's) website (www.trb.org under the [R&T Partnership](#) link). The participants' affiliations are listed in the Preface.

Special recognition is due to the following chairs and secretaries of the five working groups:

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4. Policy Analysis, Planning, and Systems Monitoring

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5. Planning and Environment

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Further, special thanks are due for the extensive involvement of the liaisons from federal agencies and related American Association of State Highway and Transportation Officials (AASHTO) committees. Funding support from the National Cooperative Highway Research Program (NCHRP) is gratefully acknowledged; NCHRP provided support for participation of liaisons from the AASHTO committees and for Robert E. Spicher to prepare this summary report.

Summary

Progress does not just happen—it comes from innovation, and innovation results from research and technology (R&T). One can only imagine the exchange of words between aviation innovators Orville and Wilbur Wright after their first plane crashed. A good guess might be: “We need more research!” The progress resulting in the field of aviation from the Wright brothers’ early experiments is clear to everyone. Progress in the highway field, although perhaps not quite so dramatic and obvious as that in the aviation field, has been tremendous. The U.S. highway system is the envy of the world, and R&T has played a critical role.

The phrase “we need more research” has been fully embraced by the highway research community, and it can be found on the final page of almost every research report. In this report, the phrase has added significance in that it represents the principal finding of this initiative. It is important for the reader to understand at the outset that this is not still another call *only from researchers* for more research. This time, the call comes from a broad representation of the highway community—the owners and operators of the highways, numerous highway-related industries, and, yes, researchers. The findings in this report were developed through the efforts of hundreds of individuals from more than 170 organizations; input was invited from anyone who wished to participate. *This effort is unprecedented in terms of scope and outreach.*

AUDIENCE

This report identifies current needs for R&T to address national issues and proposes new approaches to developing R&T programs. The findings will be of particular interest to federal agencies, the American Association of State Highway and Transportation Officials (AASHTO), state departments of transportation (DOTs), industry organizations, universities, and research institutes that sponsor highway R&T programs. Of course, the report also should be useful to the primary providers of funding—the U.S. Congress and the state legislatures.

PURPOSE

The report’s purpose is twofold: first, to identify highway R&T needs to assist sponsoring organizations as they develop their R&T programs and second, but importantly, to demonstrate the value of a partnership approach to carrying out national R&T. As used herein, “R&T” is defined as basic and applied research, including the design and testing of new technologies, but not the manufacture, implementation, or transfer of those technologies.

This report is a product of the National Highway R&T Partnership, a group convened in late 1998 by the Federal Highway Administration (FHWA), AASHTO, and the Transportation Research Board (TRB) to engage the full highway transportation community in the identification of R&T needs and to address the benefits to be realized by forming partnerships to fulfill those needs. This report deals primarily with the needs-identification phase.

It should be noted that the R&T needs identified during the partnership’s work do not distinguish among those that may be funded through existing programs (e.g., FHWA and the National Cooperative Highway Research Program [NCHRP]), planned new ini-

tatives (e.g., the Future Strategic Highway Research Program [F-SHRP]), or additional funding that would be required for the unmet needs. In effect, the working groups identified total needs within their areas of interest, without specifying the funding source.

National R&T needs were identified in the following five areas.

1. Safety
2. Infrastructure Renewal
3. Operations and Mobility
4. Policy Analysis, Planning, and Systems Monitoring
5. Planning and Environment

Presented herein is a broad range of current R&T needs, developed with extensive input from the highway community. Although not totally inclusive of the entire range of highway issues deserving R&T, the broad themes identified within the above areas certainly cover a wide spectrum of needs, many of which relate to crosscutting issues. Similarly, although the partnership participants, who were all volunteers, did not include every segment of the highway community, their input is representative of a broad spectrum of that community.

THE NEED FOR GREATER INVESTMENT

Approximately one-half of 1 percent of public-sector highway spending is allocated for R&T, an amount that is much less than in practically any other industry. Nonetheless, highway research has been a major contributor in providing the United States with the most extensive highway system in the world. National highway R&T needs identified to date by the partnership participants total more than \$700 million per year (see Table S-1), and this amount does not represent total needs. The partnership's work to date has not fully covered all areas, such as maintenance, intelligent transportation systems, and geometric design. Further, the national R&T needs estimates in this report do not include other activities related to R&T, such as technology transfer and implementation. Although the partnership's activities have not determined the total funding level that may be needed, it appears that the total could well approach an estimate of the American Road and Transportation Builders Association (ARTBA). ARTBA is calling for a \$1 billion annual investment for highway-related R&T programs when the federal surface transportation programs are reauthorized in 2003.

Determining the exact level of expenditures currently being devoted to national highway R&T needs is difficult because of the number of sponsors involved, the combination of R&T with implementation and technology transfer in some programs, and the distinction between national versus state and local R&T (and it should be noted that state and local governments have significant R&T needs as well). An approximation of current expenditures on national R&T (by FHWA, the National Highway Traffic Safety Administration [NHTSA], the Federal Motor Carrier Safety Administration [FMCSA], and NCHRP) indicates that *the current funding level would not cover even half the partial needs identified herein, much less the full needs*. It is clear that a major R&T investment is required to develop the innovations necessary to allow the highway system to meet future demands. R&T investments, along with the resources to implement the resulting advancements, will ensure that the U.S. highway system will continue to be the envy of the world and will play a vital role in the country's economic expansion.

Consider the following short list of evidence supporting the need for additional R&T, which contains one example from each of the five R&T areas reported herein, selected from extensive supporting information contained later in the report:

1. *Safety*—“If existing trends continue, the equivalent of every man, woman, and child living in the following states and District of Columbia will be injured or killed by 2010 (in highway crashes); Alaska; Arizona; Connecticut; Delaware; Washington, D.C.; Hawaii; Idaho; Iowa; Kansas; Maine; Mississippi; Montana; Nebraska; Nevada; New Hampshire; New Mexico; North Dakota; Oklahoma; Oregon; Rhode Island; South Dakota; Utah; Vermont; West Virginia; and Wyoming.”
2. *Infrastructure Renewal*—“. . . in 1998, Dr. Anthony Kane, former Executive Director of the Federal Highway Administration, reported that 7,000 miles of the 24,000 miles of urban interstates and freeways needed pavement replacement and that another 5,000 miles would need replacement in a few years.”
3. *Operations and Mobility*—“The cost of congestion in U.S. cities is increasing by 7 percent annually, and very conservative estimates place that cost in 68 major cities to currently be in excess of \$70 billion per year.”
4. *Policy Analysis, Planning, and Systems Monitoring*—“As America enters the new century, it faces dramatic changes in the nature of its population and its economy, changes in the world economic structure in which it competes, and [changes in] the technologies that will be employed. All of these forces of change will affect transportation both directly and indirectly and will affect how transportation interacts with the the society, the economy, and the environment.”
5. *Planning and Environment*—“The U.S. Environmental Protection Agency is currently predicting that by the year 2005, growth in vehicle miles traveled will begin to surpass and obviate the benefits achieved in air quality from technological change, e.g., cleaner fuels.”

Increased investment in R&T funding is, of course, just part of the solution. Clearly, funding requirements to actually build and improve the infrastructure and to carry out the many programs needed to improve the safety and efficiency of highway transportation are the more important needs. According to the report *1999 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance—Report to Congress*,¹ capital expenditures of \$94 billion per year are needed on the highway system. Current capital expenditures by all levels of government are approximately \$54 billion, accounting for only 57 percent of the actual needs. Although this shortfall represents the most important need, it also illustrates the need for R&T funding because, in a climate of limited resources for construction, as well as for operations and maintenance, making the best use of those limited resources is critical. To that end, R&T investment is needed to ensure that the most cost-effective products, procedures, and processes are available to highway agencies.

MANAGING THE R&T PROCESS

This report also contains a conceptual description of how national research programs should function to ensure the best use of limited resources. Although still preliminary and conceptual, the process described provides an excellent basis for continuing the dialogue

¹ *1999 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance—Report to Congress*, Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation (2000).

and building on the objective of forming partnerships to achieve a national program—a program involving all players in a way that helps sponsors meet their constituencies' needs.

NEXT STEPS

Research sponsors should find the R&T needs identified herein useful as they develop their current and future programs. The report should be of particular interest to FHWA, FMCSA, the Federal Transit Administration (the Transit Cooperative Research Program), NHTSA, AASHTO (NCHRP), the state DOTs, industry, and the University Transportation Research Centers and academia. The findings will also be useful to other initiatives directed to the development of national highway R&T programs, including, but not limited to, F-SHRP, the Surface Transportation Environmental Cooperative Research Program, the Research and Technology Coordinating Committee, and the Intelligent Transportation Society of America's Ten-Year Program Plan and Research Agenda.

Individuals or organizations wishing to participate in future activities of the partnership should contact Mark Norman at TRB (mnorman@nas.edu).

TABLE S-1 R&T themes and costs

WORKING GROUP	THEMES	ANNUAL COSTS (millions of \$)	TIME PERIOD (years)
Safety	1. Safety Management and Data Systems	10	5
	2. Driver Competency	20	5
	3. High-Risk Driving	40	5
	4. Light-Duty Vehicle Safety	20	5
	5. Highway Infrastructure and Operations	30	5
	6. Vulnerable Road Users	10	5
	7. Heavy Truck and Bus Safety	10	5
	8. Post-Crash Management	10	5
		SUBTOTAL	150
Infrastructure Renewal— Asset Management	1. Information Management	5	10
	2. Decision Support Tools	5	5
	3. Implementation	1	3
	4. Education	2	10
Infrastructure Renewal— Pavements	1. Designs and Materials	50	6–8
	2. Construction and Maintenance Techniques and Technologies	50	6–8
	3. Safer, Environmentally Friendly Pavements	10	6
	4. Education, Communication, and Job Training	25	6
	5. Promotion and Delivery of Innovation	25	6

(continued)

TABLE S-1 R&T themes and costs (continued)

WORKING GROUP	THEMES	ANNUAL COSTS (millions of \$)	TIME PERIOD (years)
Infrastructure Renewal— Highway Structures	1. Enhanced Materials, Structural Systems, and Technologies	15	5
	2. Efficient Maintenance, Rehabilitation, and Construction	10	5
	3. Safety Assurance of Highway Structures for Extreme Events	15	5
	4. Assessment and Management of Bridges and Other Structures	10	5
	5. Enhanced Specifications for Improved Structural Performance	10	5
	6. Information and Automation for Structure Design, Construction, and Maintenance	10	5
	SUBTOTAL	243	
Operations and Mobility	1. Customers, Customer Expectations, and Customer Needs	6	5
	2. Maximizing Efficiency and Minimizing Congestion	48	5
	3. Information Needs and Requirements	12	5
	4. Transportation Safety	12	5
	5. Environmental Issues	6	5
	6. Intermodal Issues and Efficiencies	18	5
	7. Research Program and Process	–	–
	8. Crosscutting Issues	18	5
SUBTOTAL	120		
Policy Analysis, Planning, and Systems Monitoring	1. Improving Understanding of Interactions Between Transportation and Society	4	5–10
	2. Enhancing Data-Driven Decisionmaking Tools	7	5–10
	3. Improving Monitoring of Evolving Trends	13	Continuing
	4. Advancing Multimodal Transportation Planning	42	3–10
SUBTOTAL	66		
Planning and Environment	1. Human Health	*	
	2. Ecology and Natural Systems		
	3. Distributional Aspects		
	4. Emerging Technologies		
	5. Land Use		
	6. Planning and Performance Measures		
SUBTOTAL	150	5	

* The Planning and Environment Working Group did not breakdown specific costs for each theme.

1

INTRODUCTION

On your next trip by automobile, look around. The trip need not be long; the drive to work or the shopping center will suffice. Notice the attractively designed bridges, the median and interchange landscaping, the stone-faced noise barriers, and the other aesthetic features designed to make your trip more enjoyable. Perhaps less obvious are the pavement edge markings, the buried ends of guardrails, the crash cushions in gore areas, the roadside call boxes and state trucks providing motorist assistance, the gentle side slopes and wide shoulders, and a host of other features to make your trip safer and more enjoyable. Notice the coordinated traffic signals, right-turn-on-red-after-stop provisions, automatic toll collection booths—all designed to minimize your travel time. And although it is not obvious to you as you drive, the highway is constructed of longer-lasting pavements, well-designed subbases, structurally sound bridges, and traffic-monitoring systems—all in place to provide cost-effective and efficient travel. Of course, not all highways have been upgraded to include the latest improvements, and much remains to be done.

These features are just a few examples of the care and attention paid by the highway agencies to ensure pleasant, safe, and efficient travel to the public. *Every highway feature results from innovation and the research and technology (R&T) needed to develop those innovative ideas.* Progress to date has been truly remarkable in light of limitations in funding for highway development and operations, as well as limitations on highway research funding. Approximately one-half of 1 percent of public-sector highway spending is allocated for R&T, an amount that is much less than in practically any other industry. Nonetheless, highway research has been a major contributor in providing the United States with the most extensive highway system in the world, a system that accommodates more than 2.6 trillion vehicle miles of travel each year, moves 1.1 trillion intercity ton-miles of goods, and does so at a cost of less than 10 percent of the motorist's driving expenses.

Although past accomplishments in highway transportation are both impressive and relatively easy to visualize (just visit a transportation museum or talk to your parents or grandparents), future safety and mobility needs are more difficult to comprehend. A few clues include an increase in passenger miles per capita of 40 percent by 2025 (compounded by an increase in population of 100 million people by 2025); an increase in goods movement of almost 80 percent over the same time period; a continuation of economic growth; and changing travel demands that will result from a variety of factors such as demographic shifts, telecommunications, and increased use of air transportation and transit. As a result, the types of highway innovations that are needed in the future are difficult to imagine. Further, although past accomplishments are impressive, many current problems are still in need of solutions: on your trip to work, you may have also noticed heavy congestion, a traffic crash, and potholes.

The uncertainty of future transportation changes and the R&T requirements to meet those changes, along with the problems that already exist today, make it clear that there is a continuing need, in fact a greater need, to provide resources for innovation. This report identifies a broad range of R&T areas that, while not all-inclusive, should be useful in developing future R&T programs.

BACKGROUND

Highway research in the United States is both extensive and decentralized. It is extensive in the sense that it covers a broad range of concerns confronting the highway community, from national and state policy issues (such as regulation and environmental concerns) to local technical concerns (such as concrete mix design and traffic signal timing). It is decentralized in the sense that numerous sponsors of research develop their own R&T programs to meet their particular needs. Sponsors include federal agencies, such as the Federal Highway Administration (FHWA), the Federal Motor Carrier Safety Administration (FMCSA), the Federal Transit Administration (FTA), and the National Highway Traffic Safety Administration (NHTSA); state departments of transportation (DOTs) and other state agencies; the National Cooperative Highway Research Program (NCHRP) and the Transit Cooperative Research Program (TCRP); industry groups, such as the National Asphalt Pavement Association (NAPA) and the American Concrete Pavement Association (ACPA); automobile manufacturers and other manufacturers; universities and University Transportation Research Centers; and research institutes. Additional information describing the programs and activities of some of the above organizations can be found in the paper prepared by the Operations and Mobility Working Group, which is posted on the Transportation Research Board's (TRB's) website (www.trb.org).

ROLES OF R&T SPONSORS

Each sponsoring organization defines its role in conducting R&T in accordance with the issues of the most direct interest to the organization (e.g., national issues versus local concerns). However, the nature of the highway business produces many shared interests among organizations. Take, for example, the pavement area. One could possibly identify the *primary* interest of each sponsor as follows:

- FHWA—assurance that federal funds are used effectively.
- State DOTs—development of standards meeting the individual state's situation.
- NCHRP—development of design and construction practices applicable to all states.
- Academia—fundamental research on material properties.
- Industry—development and marketing of the final product.

From such a simplistic description of primary interests, it is clear that each interest builds on and interacts with the others and that a separation of responsibility designed to eliminate overlap is neither possible nor desired. On the contrary, what is desired in the pavement area, as well as in all other R&T areas, is full cooperation and coordination among sponsors as each meets its own charge in a way that facilitates the work of the others.

Considerable effort has been devoted over the years to coordinate these various programs to ensure that they are complementary and to avoid duplication. One may think that a single, long-range research plan, developed cooperatively with all parties, should exist, along with an indication of which group should conduct each plan element. However, such a plan has not been produced and is probably neither feasible nor desirable. Obtaining total concurrence among agencies with different and, in some cases, competing interests is probably not realistic. Optimal solutions may vary by region, and alternative approaches to the same problem may yield greater results. Further, research budgets vary considerably among agencies and vary year-to-year within an agency, making long-range budget planning difficult. Rather than operating under a single research plan for all parties, sponsors have focused on the identification of R&T needs within their own agency, with varying levels of input from the broader highway community.

In addition, special initiatives, such as the Strategic Highway Research Program (SHRP) and Future Strategic Highway Research Program (F-SHRP) have been conducted to identify high-priority research needs from which each sponsor can select areas of interest or for which separate funding could be obtained, or both. This report contains the findings from such a special initiative—the National Highway R&T Partnership.

REPORT SCOPE AND LIMITATIONS

The scope of this report, reflecting the partnership's activities to date, covers a broad range of highway R&T. Included are R&T related to national policy issues; environmental and social concerns; safety; intelligent transportation systems; and technical aspects of planning, design, construction, operations, and maintenance.

This report includes research needs at the "theme level." A theme is defined as a broad area of research (e.g., roadside safety) rather than specific projects (e.g., guardrail design), although examples of specific projects are included.

Some areas did not receive as much attention as they warranted because of time and resource constraints. For example, highway maintenance is an area of growing need, but is not treated extensively in the report. Similarly, geometric design was not fully treated. Both maintenance and design are addressed as part of the other areas, but not to the extent they would have been if treated as separate major areas. The operational aspects of intelligent transportation systems research are included in the Operations and Mobility Working Group report; however, the full range of intelligent transportation systems research is not included because these needs are being addressed by the Intelligent Transportation Society of America (ITS America). Although the report is not, therefore, totally inclusive, it does provide a sense of the magnitude and range of highway-related R&T needs.

Priorities were not determined among the five R&T areas covered by the partnership's working groups. Because the partnership is an ad hoc effort with limited opportunity for interaction among the groups, it was determined that priorities should not currently be established. The individual working group reports do address priorities to some extent within their respective areas.

The cost estimates cover the conduct of research, development of technology, and development of an implementation plan, but not the actual implementation and technology transfer. Implementation and technology transfer are, by definition, critical to carrying out

the innovations determined through R&T and should be addressed during the conduct of R&T. Implementation and technology transfer costs are directly dependent on the actual R&T findings and, therefore, cannot be estimated at this stage. Further, the R&T cost estimates are ballpark figures without the benefit of detailed calculations, which will be possible only when specific R&T projects are determined and scoped.

Most of the statistics included in this summary report were taken directly from the individual working group reports. Input to those reports came from many sources and individuals, and the statistics were not always referenced to a specific source. In many cases, the numbers cited by the working groups are not attributed to specific sources, but can be considered to be the best estimates by some of the leading experts in transportation.

REPORT ORGANIZATION

The next section describes the National Highway R&T Partnership—its background, purpose, and charge. The following section discusses R&T needs. It includes a summary of the R&T recommendations developed by the working groups, followed by a conceptual proposal outlining an approach for conducting national R&T. The final section addresses potential uses of the report and describes future activities of the partnership.

Note that the real substance of the partnership's effort is in the papers from the individual working groups (go to www.trb.org and click on [R&T Partnership](#)). The reader should review these carefully to gain a fuller understanding of the identified R&T needs in each area and the supporting information illustrating the need for funding.

RELATED ACTIVITIES

While the partnership was being created and during the time the working groups were preparing their reports, a number of related R&T needs-identification efforts were conducted. Several of these efforts are aimed at providing input to the next surface transportation reauthorization by defining areas of consensus within the highway community. These special efforts are, of course, in addition to the continuing R&T needs-identification processes employed by the various sponsors identified above in the Background section. A brief summary of each of the special efforts follows.

Research and Technology Coordinating Committee

With support from FHWA, TRB has convened the Research and Technology Coordinating Committee (RTCC), which provides continuing guidance and advice on the nation's highway research program. The RTCC charge is to take a broad view of highway research that is not restricted to a particular program, topic area, or agency. Committee membership includes top-level administrators, researchers, and practitioners from state governments, academia, and industry. The RTCC periodically issues reports documenting its findings and recommendations.

This report was provided to the RTCC for consideration in the development of its recommendations related to the federal role in highway research. The RTCC report

will be published as *TRB Special Report 261: The Federal Role in Highway Research and Technology*.

Future Strategic Highway Research Program

In 1987, Congress authorized SHRP, which was a highly focused, \$150 million, 5-year effort designed to improve the performance of highway materials and highway maintenance practices. SHRP has received considerable support because it set clear goals and focused applied research, funded from the Highway Trust Fund, on solving major problems facing highway agencies and the motoring public. When the focus of the SHRP effort shifted to implementation of results, Congress requested that TRB initiate a new process of setting priorities and designing a program for another focused R&T effort. The resulting study, F-SHRP, was initiated in January 1999 and was completed in October 2001.

F-SHRP's major activities were as follows:

- Establish a committee to guide work and to author a report to Congress.
- Conduct an outreach to major stakeholders to identify potential areas of focus for the future research program.
- Develop and apply criteria to select actual focus areas for research programs.
- Develop a research agenda.
- Develop funding needs and an administrative structure.

The principal TRB contact for this program is Ann M. Brach, Study Director (abrach@nas.edu). The final report has been published as *TRB Special Report 260: Strategic Highway Research—Saving Lives, Reducing Congestion, Improving Quality of Life*.

Continuous communication between the partnership effort and F-SHRP has provided mutual benefits. While each group is making its own needs evaluation, considering each other's findings has been useful. Also, F-SHRP has placed a greater emphasis on setting priorities and identifying one or more areas in which a concerted effort and dedicated funding are likely to result in major breakthroughs with tangible benefits. It is too early in the F-SHRP effort to make a final comparison between F-SHRP's findings and those of the partnership.

Surface Transportation Environmental Cooperative Research Program

The Surface Transportation Environmental Cooperative Research Program (STECRP) Advisory Board is serving a dual role—first, to accomplish its basic charge as described in this section and second, to serve as one of the five working groups of the partnership (Planning and Environment). Because the board was in operation when the working groups were initiated, and in view of the objectives common to the two efforts, creating a separate working group would have been duplicative.

Established in response to provisions in the Transportation Equity Act for the 21st Century (TEA-21), the Advisory Board is charged with developing a national agenda for energy, environment, and planning research related to surface transportation. It is envi-

sioned that this agenda will be used by federal agencies and Congress in setting national research priorities and in establishing collaborative partnerships. The National Research Council (NRC) formed the Advisory Board in November 1999. The Advisory Board comprises 17 members representing an array of expertise and a broad spectrum of the transportation and environmental communities, including academia, state DOTs, state environmental protection agencies, metropolitan planning organizations, transit organizations, environmental groups, and industry. The scope of the Advisory Board's mandate extends beyond the highway community.

Regarding its primary task to formulate a national research agenda, the Advisory Board intends to produce a report that will identify and prioritize both the critical research areas and the research needs necessary for conducting a "systems-level" examination of surface transportation's impact and effect on the environment. The Advisory Board will also examine the role of institutions and institutional structures as part of its report and will provide recommendations for designing, prioritizing, and managing research.

On September 25 and 26, 2000, the Advisory Board invited transportation and environment professionals from across the United States to participate in a "Research Priorities" workshop. Four key themes emerged from the workshop, which are currently shaping the Advisory Board's thinking. The key themes are as follows:

1. *Community and Connectivity*: an integrated, user-oriented systems approach to transportation and the environment.
2. *Healthy Communities*: extending the focus of transportation beyond traditional highway and pavement issues to considering a community's health—for example, the impacts of air quality, noise, and congestion on an individual's quality of life.
3. *Reconnecting to Nature*: developing new transportation planning processes that actively incorporate environmental stewardship and environmental concerns from a systems-level perspective into the design and maintenance of transportation facilities.
4. *Equity*: ensuring that the needs and concerns of all communities are factored into the transportation planning and decisionmaking process.

AASHTO's Standing Committee on Research

AASHTO's Standing Committee on Research (SCOR) is responsible for developing AASHTO's interest and participation in research and for overseeing NCHRP on AASHTO's behalf. SCOR's mission is to support AASHTO member departments and committees through effective research, development, and technology transfer. It facilitates access to accurate information, new products, and innovative procedures and operating systems. SCOR ensures that transportation research funds address critical national needs, complement and supplement federal and state programs, and have a high value. SCOR's strategic goals are as follows:

- Champion the value of research results to member departments, the transportation industry, and the traveling public;
 - Address AASHTO's business needs through research planning and programming;
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- Provide the necessary coordination to ensure that research is managed effectively and efficiently;
- Disseminate and facilitate the deployment and evaluation of research and innovation;
- Advocate the need for and seek appropriate research funding levels; and
- Develop and sustain an appropriate management framework and committee organizational structure.

SCOR is an active partner in the partnership's activities. Periodic briefings are provided to the full committee, and liaisons from the appropriate AASHTO committees provide continuous coordination to the working groups. SCOR intends to use the material produced by the partnership's working groups to develop an AASHTO research and technology plan to be carried out under the next federal-aid highway reauthorization.

Ten-Year Program Plan and Research Agenda for Intelligent Transportation Systems in the United States

This plan is being developed through a multipronged effort of data gathering and analysis and consensus building. It was motivated by the requirements in TEA-21 for a program plan with a 10-year horizon for goals and objectives. The U.S. Department of Transportation (U.S. DOT) and ITS America established a steering committee representing the public, private, and academic sectors. Issue papers were solicited from the intelligent transportation systems community at large, and environmental scans were developed. An industry summit was held in April 2001 to review a draft plan. Following approval by the steering committee and ITS America's Coordinating Council and Board of Directors, the plan was submitted as formal advice to the U.S. DOT in late 2001.

The purpose of the plan is as follows:

1. To state, motivate, and explore the premise that this kind of investment in research, development, and deployment is good policy for both public and private decision-makers. Such policy will result in substantial savings of lives, time, and money; in materially improved capabilities for effectively moving people and freight; and in meaningful improvements in environmental and other quality-of-life issues.
2. To outline the programs and activities that need to be undertaken by public agencies at multiple levels, by private industry, by research establishments, and by transportation professionals in order to meet the promise of intelligent transportation systems.

The plan will be based on five benefit themes: safety, efficiency, economy, mobility, and environment and quality of life. The structure will include facilities and infrastructure, the vehicle, and customer information.

Information regarding the partnership's activities and findings were shared throughout the process with the ITS America Research Program Committee for coordination purposes.

2

APPROACH

With the numerous activities described in the previous section, the obvious question is why was another (i.e., the partnership) needed to identify R&T needs? Recalling that the highway research program is both extensive and decentralized provides the answer. The impetus for creating the partnership came from recognition of the need and desire to involve all interested individuals and agencies in the development of a broader understanding of R&T needs and to identify ways in which the various players can better coordinate their efforts through partnerships.

The partnership was initiated by FHWA, AASHTO, and TRB. Participation is open to all who are interested and willing to contribute, and hundreds of individuals and more than 170 organizations have participated in the work to date. The partnership seeks to develop a new framework for coordinating highway R&T activities among research sponsors, practitioners, researchers, and other stakeholders in highway transportation. The framework will supplement existing mechanisms for managing research, providing opportunities for collaboration between researchers and practitioners, or disseminating research findings.

More specifically, the framework has four goals. They are as follows:

1. To make R&T investments more effective and efficient through broad-based stakeholder involvement and greater interaction among different research programs and program sponsors.
2. To foster a better awareness and appreciation of existing research programs—a sense of ownership that extends beyond the research sponsors.
3. To stimulate the formation of productive R&T partnerships, which could include jointly funded projects, closely coordinated projects funded by different sponsors, research consortia, and joint public–private initiatives.
4. To help demonstrate needs and opportunities for research and the potential payoff from research investments, and thereby to help expand the constituencies for highway R&T.

Five working groups were created within the partnership in the following areas:

1. Safety
2. Infrastructure Renewal
3. Operations and Mobility
4. Policy Analysis, Planning, and Systems Monitoring
5. Planning and Environment

These five R&T areas were taken from FHWA's major program categories and were considered by the partnership to provide an excellent structure for the partnership's initial activities. For Planning and Environment, in a separate effort independent of the partnership's activities, TRB, on behalf of FHWA, had previously established an Advisory Board for STECRP. Because the charge of STECRP is similar to that of a working group, a new group was not established. The topic of planning was included in the scope of two working groups—STECRP for environment-related planning and the policy working group for other aspects of planning.

Each working group was asked to

1. Identify the major issues in its area of interest;
2. Review existing R&T programs, including FHWA, AASHTO/NCHRP, state DOTs, and others being conducted in the working group's area of interest;
3. Assess the coverage in relation to the current issues and identify gaps and areas of overlap;
4. Determine priority research areas;
5. Develop marketing information on the benefits to result from research expenditures; and
6. Facilitate partnerships and coordination to carry out needed research.

The working groups were asked to deal primarily with research themes rather than with individual projects (e.g., roadside safety rather than barrier design). Basic and applied research were addressed. The working group findings, including suggestions for new emphasis areas and coordination among programs, will be made available to research sponsors and the RTCC for their consideration.

Working group chairs were drawn from state DOTs, universities, and research centers. Staff from FHWA, FMCSA, FTA, NHTSA, and other federal agencies and AASHTO committee representatives acted as liaisons to various groups for coordination purposes, and TRB staff were assigned as secretariat to each group (see following list).

From Fall 1999 to December 2000, each working group solicited participation by interested parties and each held one to three meetings to obtain input. Each group made periodic presentations to the RTCC and AASHTO's SCOR and Research Advisory Committee (RAC).

In November 2000, each working group's draft report was placed on TRB's website for review and comment by all who wished to participate. In addition, a session was held on January 9, 2001, at the TRB Annual Meeting to present the preliminary findings. Following the Annual Meeting, the draft reports were finalized and are included on TRB's website (go to www.trb.org and click on [R&T Partnership](#)).

CHAIRS AND CONTACTS

The following lists the working group chairs and TRB staff contacts:

Safety

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R&T NEEDS

THE NEED FOR GREATER INVESTMENT

Regardless of the area (e.g., health care or transportation), illustrating the need for greater investment in research is a difficult task. Although the potential benefits can be expressed (and agreed to) in qualitative terms, tying actual quantitative results to expenditures is nearly impossible. Most efforts to do so resort to anecdotal information, describing the nature and scale of the problem, offering potential promising solutions along with some indications of likely benefits, and then providing cost estimates. This report is no exception. Following is a description of some of the challenges now being faced by the highway community. Potential solutions and benefits are presented in the form of R&T themes and emphasis areas identified by each working group. Cost estimates are shown in Table 1 (tables are grouped at the end of the text).

The Challenges

Inadequate funding for highway R&T is a major problem. The national R&T needs identified by the partnership's working groups total more than \$700 million per year, and this is only part of the picture. This total does not account for some R&T areas—such as maintenance, some aspects of intelligent transportation systems, and geometric design—that were not fully covered in the effort. The figure of \$700 million also does not include other activities related to R&T, such as implementation and technology transfer. A comparable figure for current expenditures for national highway R&T (also excluding implementation and technology transfer) is difficult to determine because of the number of sponsors, the combination of R&T with implementation and technology transfer in some programs, and the distinction between national versus state and local R&T. Nonetheless, it appears that the current funding level for R&T would cover less than one-half of the needs identified by the partnership, and, again, these are not the total needs.

It should be noted that the R&T needs identified during the partnership's work do not distinguish among those that may be funded through existing programs (e.g., FHWA and NCHRP), planned new initiatives (e.g., F-SHRP), and additional funding that would be required for the unmet needs. In effect, the working groups identified total needs within their areas of interest without specifying the funding source.

The challenges facing the transportation community clearly indicate that a viable R&T program is needed. The following list of challenges is taken directly from four of the individual working group reports. The fifth working group report—Policy Analysis, Planning, and Systems Monitoring—identifies R&T needs that are aimed at providing policymaking tools and information in general support of addressing all the following specific challenges. Only selected items are included to provide the reader with a general sense of the challenges facing the highway community. It is important

The Highway Safety Challenge

to note that these challenges represent a real threat to the ability of the highway system to serve its fundamental purpose—the efficient movement of people and goods—as well as its ability to continue its critical role in allowing economic development to occur at the desired pace.

The reader should review the Safety Working Group report for additional information.

The Problem

- In 1999, 41,611 people were killed on our nation's roads.
- If existing trends in crashes continue, the equivalent of every man, woman, and child living in 24 states and the District of Columbia will be injured (including disability-causing and minor injuries) or killed by 2010.
- Although accident rates have shown an impressive decline during the past 8 years (from 1.9 fatalities per 100 million vehicle miles of travel to 1.5 fatalities per 100 million vehicle miles of travel between 1991 and 1999), the total number of fatalities remains too high—more than 41,000.
- Pedestrian, bicycle, and motorcycle fatalities account for approximately 20 percent of all highway deaths. In 1999, 4,987 pedestrians, 750 bicyclists, and 2,472 motorcyclists died in motor vehicle crashes. Approximately 188,000 pedestrians, bicyclists, and motorcyclists were injured.

The Costs

- The cost of traffic crashes in 1999 was \$181 billion.
- Economic costs to society will approach \$2 trillion over the next 10 years.

The Crash Locations

- The highway infrastructure is a contributor to the number and severity of crashes—as much as 15 to 20 percent of all crashes and highway fatalities.
- About 50 percent of all crashes occur at intersections.
- One-third of all motor vehicle crashes occur when the vehicle leaves the road.
- In 1999, 868 people died in work zones.

The Driver

- Annually, more than 6,000 fatal crashes involve drivers with invalid or revoked licenses.
 - Eighty-five percent of the factors contributing to crashes are in some way related to the behavior of the driver.
 - Novice drivers (those just beginning to drive) represent approximately 7 percent of the driving population, 14 percent of the crash population, and about 20 percent of the fatal crash problem.
 - Use rates for safety belt restraints in the United States lag far behind many other countries, and more than 18,000 unbelted people died in crashes in 1998. Airbags used in conjunction with lap/shoulder belts can reduce the risk of fatalities by 50 percent.
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The Deteriorating Infrastructure Challenge

The reader should review the Infrastructure Renewal Working Group report for additional information.

The Problem

- In 1998, Dr. Anthony Kane, former Executive Director of FHWA, reported that 7,000 miles of the 24,000 miles of urban interstates and freeways needed pavement replacement and that another 5,000 miles would need replacement in a few years. The condition of the rural portion of the National Highway System is better, but still more than 13,000 centerline miles of this 111,000-mile system show pavement roughness that requires immediate attention, and another 15,000 miles are approaching that state.
- Approximately 14 and 16 percent of the bridge inventory (583,000 bridges) fall into the functionally obsolete and structurally deficient categories, respectively. Furthermore, states are experiencing increased problems with the deterioration and even failure of other highway structures, such as retaining walls, culverts, sign structures, and light standards.

The Costs

- In 1998, federal, state, and local governments invested about \$107 billion in the highway system.
- In 1997, \$31.8 billion in capital investment was estimated to be required to maintain 1995 conditions on the National Highway System. However, only \$23.2 billion was actually spent.
- Approximately \$17 billion is spent on pavement-related projects each year.
- In 1997, nationwide expenditures related to system preservation and construction of new highway bridges was \$7.1 billion from federal, state, and local funds.

The Congestion Challenge

The reader should review all of the working group reports for additional information.

The Problem

- Over the last 30 years, vehicle miles traveled have nearly tripled, the number of drivers has increased by 70 percent, and the number of vehicles has doubled.
 - Over the past 15 years, new road mileage has risen a mere 1 percent. In recent years, construction of new roadways has occurred at about half the pace that would be necessary to simply maintain levels of congestion.
 - Since 1970, on the rural interstate system, the average daily traffic volume has more than doubled, and the average daily load (equivalent single-axle loads [ESALs]) has increased nearly sevenfold.
 - From 1977 to 1995, long-distance travel grew more than 60 percent.
 - Shopping trips have been one of the fastest growing of trip purposes, almost doubling in miles of travel from 2,500 miles per household in 1983 to 4,600 miles in 1995, approaching 14 percent of total household travel.
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- The number of multivehicle households has increased from 31 percent in 1969 to nearly 60 percent in 1995.
- At the beginning of the twenty-first century, 180 million people, 60 percent of the U.S. population, resided in the 50 metropolitan areas with more than a million people.

The Costs

- The cost of congestion in U.S. cities is increasing by 7 percent annually, and very conservative estimates place the cost in excess of \$70 billion per year.
- From 1982 to 1997, delay per driver in 68 urban areas increased by 181 percent; from 1992 to 1997, it increased by 29 percent. From 1982 to 1997, travel volumes under congested conditions in those 68 urban areas has doubled.
- Potential safety benefits resulting from improved operations may be \$25 billion per year.

The Environmental Challenge

The reader should review the forthcoming Planning and Environment Working Group (STECRP) report for additional information.

The Problem

- Over the next 25 years, the population of the United States is predicted to grow by 60 million people, the gross domestic product is projected to reach 29 trillion dollars (approximately 1.5 times today's levels in constant dollars), and annual passenger miles traveled are expected to increase from 5 trillion miles in 2000 to 8.4 trillion miles in 2025.
- Current vehicle and fuel technologies, highway design and operation practices, institutional arrangements, travel habits, and development patterns are producing unacceptable damage to human and environmental health—from direct pollution from exhaust, through loss of life and limb, and from the permanent alteration of prime habitat through road construction.
- Heavy reliance on the private vehicle for travel (currently more than 90 percent of all personal travel) has been a significant contributing factor in the broad spread of urbanized areas: the amount of land devoted to residential and commercial land, parking, and streets is increasing at a far faster rate than is population.

The Impacts

- The U.S. Environmental Protection Agency (U.S. EPA) is currently predicting that by the year 2005, growth in vehicle miles traveled will begin to surpass and obviate the benefits achieved in air quality from technological change (e.g., cleaner fuels).
 - Motor vehicles are estimated to be responsible for 30 percent of all U.S. emissions of carbon dioxide, a documented greenhouse gas contributor. Additionally, 16 percent of all U.S. emissions of chlorofluorocarbons—a critical element in the destruction of the
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ozone layer—along with the release of zinc, cadmium, copper, nickel, chromium, and iron into the environment also can be attributed to motor vehicles.

- As of 1999, U.S. EPA estimates that 62 million people nationwide live in counties with pollution levels above national air quality standards and that more than 150 million tons of air pollution were released in the United States into the atmosphere in 1999.

POTENTIAL R&T SOLUTIONS AND BENEFITS

Following is a brief summary of the findings from each working group. The reader is strongly encouraged to read the full reports (www.trb.org) to gain a better understanding of the problems, issues, R&T needs, and potential benefits from satisfying these needs. Each report is well written, covers a broad range of R&T needs, and makes a convincing case for funding new R&T. Most of the following summary comments are taken directly from the individual working group reports.

Safety

Motor vehicle–related injury and death is the nation’s largest public health problem. The economic costs to society will approach \$2 trillion (over this decade).

Although this working group focused on safety, it recognized that there are safety aspects related to all five working group areas. The Safety Working Group gave primary attention to R&T needs that were not directly related to specific safety aspects of a particular discipline (e.g., construction), which resulted in minimal overlap.

For an outline of the themes and emphasis areas identified by the Safety Working Group, see Table 2. The group identified eight R&T themes.

1. Safety Management and Data Systems

Organization and management of safety, both safety operations and research, are crucial for optimal problem identification, solution development, and application and outcome evaluation. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) mandated a safety management system in each state, but the system was made voluntary 2 years later. Some states have continued the system and built it into a highly useful management tool; others have not. The objective of this theme is to develop and establish more effective, efficient, and productive techniques and processes for use in these safety management systems, as well as for other applications. Development and maintenance of comprehensive, shared, and highly integrated systems should become part of ongoing safety programs.

2. Driver Competency

Driver competency issues can be associated with up to one-third of all fatal crashes. Accordingly, even modest gains in improving driver competency can produce significant improvements in highway safety. This effort requires partnerships with diverse groups performing research in the same general area. The research organizations need to work collectively to develop effective products that can improve driver competency.

3. High-Risk Driving

Risk-taking is a predominant factor in severe crashes and an increasing phenomenon. In order to stem this trend and have an effect on highway safety, innovative solutions that are acceptable to the traveling public are needed. Finding innovative solutions that reduce risk-taking requires partnerships among all agencies performing research in high-risk driving countermeasures, as well as organizations and groups that can impact aggressive driving through implementation of new research products and services.

4. Light-Duty Vehicle Safety

Opportunities exist to improve occupant safety through vehicle enhancements in two major categories. The first category is vehicle improvements that enable the driver to recognize and possibly compensate for driver errors and, thus, reduce the frequency of crashes. The U.S. DOT's intelligent vehicle initiative (IVI) is the primary effort in this area. The second category is improving the crash survivability of vehicles to reduce the consequences of crashes when they do occur. Highway safety can be positively influenced with new underlying technologies in the entire vehicle fleet. However, strategies to pursue these opportunities will require coordinated and ongoing research initiatives among motor vehicle manufacturers, suppliers, and government.

5. Highway Infrastructure and Operations

Because many variables affect highway safety at any one time, it is impossible to estimate how much safety improvement can be attributed to infrastructure improvements. A 10-percent improvement on the 157,000-mile National Highway System could reduce fatalities by 1,000; a 5-percent improvement on the rest of the federal-aid system (800,000 miles) could reduce deaths by another 1,000. Those are reasonable goals for the infrastructure theme.

6. Vulnerable Road Users

One would expect a reduction in pedestrian, bicycle, and motorcycle fatalities with the improvement of the infrastructure. However, pedestrian, bicycle, and motorcycle safety are affected not only by infrastructure changes, but also by road user attitudes and behaviors. In addition, the design of the infrastructure is constantly faced with the trade-offs of providing optimum facilities for each type of transportation user. A 10-percent reduction in the number of pedestrian, bicycle, and motorcycle fatalities is a reasonable goal for this theme.

7. Heavy Truck and Bus Safety

The U.S. DOT has set a goal of "50 by 2010," a 50-percent reduction in commercial truck-related fatalities by the year 2010. Achieving this goal will save more than 2,500 lives annually and will prevent thousands of injuries. The annual economic cost of large truck crashes is approximately \$15 billion dollars, and the average annual per-vehicle crash cost is nearly \$6,000 for long-haul, combination-unit trucks. Crash reductions will result in large economic benefits, in addition to the human benefits of reduced injuries and fatalities.

8. Post-Crash Management

The Emergency Medical Systems Initiative (EMSI) will improve the effectiveness of care delivered by pre-hospital personnel to motor vehicle crash (MVC) victims and lead to the development of a model for EMS around the country to use for the treatment and evaluation of MVC victims. EMSI recognizes that post-crash management includes many activities, such as detection, notification, training, management, treatment, transportation, rehabilitation, and so forth. The component with the greatest need for research, however, is EMS care. This research effort requires the cooperation and commitment of the EMS and trauma research community. The long-term benefits will be profound in terms of the reduction in mortality and morbidity, not only for those injured in MVCs, but also for those involved in nonvehicle incidents.

Infrastructure Renewal

This working group addressed a broad scope associated with the renewal and preservation of the highway infrastructure. Because of the broad scope, the working group divided into three subgroups—asset management, pavements, and highway structures.

Asset Management

Asset management establishes a comprehensive framework for making cost-effective resource allocation decisions.

Asset management is receiving much national attention. AASHTO created an Asset Management Task Force in 1997, and FHWA established an Office of Asset Management in 1999.

Early benefits from transportation asset management are anticipated to include reductions in the total cost of providing transportation services. Total transportation cost includes agency costs (e.g., construction and repair) and the costs borne by facility users (e.g., vehicle operating expense, accidents, and value of travel time). Longer-term benefits will include improvements in system reliability, increased efficiency in intermodal transportation facilities, and enhanced financial performance.

For an outline of the themes and emphasis areas identified by the Asset Management Subgroup of the Infrastructure Renewal Working Group, see Table 3. The Asset Management Subgroup identified four themes.

1. Information Management

Information management activities involve hardware and software to collect, store, organize, process, assess, integrate, and ensure the compatibility of the data elements required for analytical purposes. This research theme is the highest priority of the four because asset management cannot be effectively implemented without the required data and information. Although commercial products are available to address data collection and integration, significant work will be required to modify those techniques for the public sector. Further, assistance is needed in applying state-of-the-art practices in transportation agency settings.

2. Decision Support Tools

Development of decision support tools is particularly important for those decisionmakers who own the assets; however, there is also a benefit at the national level. Asset management requires the application of a new range of analytical and presentation tools and methodologies. Five target research needs have been identified as critical: probabilistic life-cycle scenario analysis, valuation analysis, benefits determination, performance measures, and presentation of results.

Pavements

More than 13,000 miles of the 111,000-mile National Highway System (rural) show pavement roughness that requires immediate attention, and another 15,000 miles are approaching that state.

3. Implementation

Many agencies need assistance in quantifying the level of effort, process, or time required for effective implementation of asset management. For this approach to be successful, adequate resources must be devoted to the implementation process, and appropriate organizational commitment and responsibility should be clearly defined. In addition, agencies must deal with potential barriers to effective implementation.

4. Education

Education R&T opportunities include developing training materials and courses, developing delivery systems such as web-based information exchanges, and reporting on continuous monitoring and system improvement efforts through internal benchmarking efforts.

The challenge facing U.S. transportation agencies is to rebuild or rehabilitate the existing network with pavements that serve better and longer, without disrupting the local communities and regional economies that depend so heavily on the National Highway System. Unfortunately, without a national program of pavement research, this challenge is likely to go unmet. The current tools available to highway engineers, which were primarily developed in the early stages of the Interstate highway program, have been made obsolete by the growing demands placed on the nation's roadways.

For an outline of the themes and emphasis areas identified by the Pavements Subgroup of the Infrastructure Renewal Working Group, see Table 4. The Pavements Subgroup identified five themes.

1. Designs and Materials

Of all the money spent on highway capital improvements in any given year, approximately 54 percent is spent on pavements. The objective of research in this theme is to develop products that agencies can use to build new and rehabilitated pavements and preserve existing pavements that will be acceptable to users for a time period that can be reliably predicted at acceptable initial and life cycle-optimized cost.

2. Construction and Maintenance Techniques and Technologies

This theme deals with traffic management, materials, construction operations, contracting practices, and other means to enhance mobility by reducing lane and road closure and resulting delays during reconstruction, rehabilitation, and maintenance operations. Reducing lane closures during highway work will contribute to substantial economic and environmental advantages for highway agencies and taxpayers. The economic impact of the delays associated with highway construction work on commercial trucking business, the motoring public, and other businesses is tremendous.

3. Safer, Environmentally Friendly Pavements

The objective of this theme is the development of design; materials; construction; and operations techniques, procedures, guidelines, and management practices that consider the expanded use of recycled materials, reduce noise levels, and make pavement surfaces more driver-friendly and environmentally acceptable.

4. Education, Communication, and Job Training

All the various components of the nation's infrastructure renewal efforts would be wasted if there were no way to communicate information about the resulting new products and technology. A well-trained workforce is the best way to capitalize on the investment in research programs. This workforce is achieved through basic and advanced education, job training, recruitment, and technology transfer. It has sustaining benefits for public agencies, private contractors, and the public through longer-life, lower-cost, safer, and more environmentally friendly pavements. Rebuilding a well-trained workforce is critical, as the large cadre of experienced engineers, technicians, and construction workers who built the Interstate highway system is moving into retirement.

5. Promotion and Delivery of Innovation

Successful research products must be moved into practice as quickly as possible. In the past, this area has not received adequate attention, particularly with respect to funding.

Highway Structures

According to statistics reported by FHWA, approximately 14 and 16 percent of the bridge inventory fall into the functionally and structurally deficient categories, respectively.

In 1997, nationwide bridge expenditures related to system preservation and construction of new highway bridges totaled \$7.1 billion (federal, state, and local). In order to maintain the status quo, a similar level of annual investment in bridge and other highway structures will be required for years to come; even higher levels of funding will be required if the percentage of deficient structures on the nation's public roads is to be reduced. Increased investment in R&T related to highway structures has great potential for improving design, fabrication, and construction practices and will result in improved efficiency in the use of available resources.

For an outline of the themes and emphasis areas identified by the Highway Structures Subgroup of the Infrastructure Renewal Working Group, see Table 5. The Highway Structures Subgroup identified six themes.

1. Enhanced Materials, Structural Systems, and Technologies

Through more efficient design, maintenance, repair, and rebuilding of our nation's bridges and other highway structures (e.g., sign structures, tunnels, and light standards) with stronger, longer-lasting materials and structural systems, significant reductions in deficiencies and improved safety can be expected. It is possible that this can be accomplished without requiring additional resources. The objective of this theme is to advance the development and application of structural materials and systems technologies that are stronger, longer lasting, and more cost-effective for bridges and other structures.

2. Efficient Maintenance, Rehabilitation, and Construction

The objective of this theme is to identify, develop, and apply efficient technologies, processes, and administrative methods that reduce the frequency and duration of capacity reductions and reduce initial and life-cycle costs.

3. Safety Assurance of Highway Structures for Extreme Events

The objective of this theme is to improve the performance of bridges and other highway structures under the impacts of extreme events, including earthquakes, floods and scour, vehicular overload, fatigue and sudden fracture, and collision or impact forces from vehi-

cles and ships or barges. Such extreme events are the cause of the vast majority of collapses and failures of highway bridges that occur in the United States. These events lead to large-scale loss, severe economic impacts and disruptions, and, often, loss of life.

4. Assessment and Management of Bridges and Other Structures

The objective of this theme is to continue work on the development and implementation of bridge management systems, such as PONTIS and BRIDGIT. These systems provide a mechanism to foster coordinated and cost-effective maintenance, repairs, rehabilitation, or replacement of the nation's highway bridge inventory. R&T is needed to enhance the programs' data collection and evaluation methods and economic analyses.

5. Enhanced Specifications for Improved Structural Performance

The objective of this theme is to improve the cost-effectiveness, constructability, durability, and maintainability of highway bridges and other highway structures. The enhancement of existing specifications for design, materials, and construction will improve the overall effectiveness and cost-efficiency of highway bridge serviceability, integrity, and long-term performance.

6. Information and Automation for Structures Design, Construction, and Maintenance

To improve project quality and delivery time, there is a need to streamline and enhance design, construction, and maintenance processes.

Operations and Mobility

At about the same time that the partnership was being created, FHWA and the Institute of Transportation Engineers established a National Steering Committee on Transportation Operations. The intent of this committee is to build a common vision for operations, identify challenges, and identify strategies for meeting these challenges. To avoid duplication of effort, the research agenda for transportation operations was developed as part of the partnership's working group. To ensure coordination, the two co-chairs of the Operations and Mobility Working Group also serve on the National Steering Committee on Transportation Operations.

For an outline of the themes and emphasis areas identified by the Operations and Mobility Working Group, see Table 6. The groups identified seven individual themes, as well as crosscutting issues.

1. Customers, Customer Expectations, and Customer Needs

Highway agencies need to know the stakeholders who use or depend on the transportation system and their needs and expectations. This includes direct users of the system (i.e., the traveler), indirect users (e.g., those whose livelihood depends on the system), and the agencies that develop and operate the system. The objective of research in this theme is to provide the knowledge needed to encourage a cultural change toward operation in public-sector transportation agencies so that the culture becomes similar to that of the private sector, in which decisions are made based on a desire to enhance customers' satisfaction

The cost of congestion in U.S. cities is increasing by 7 percent annually, and very conservative estimates place that cost in 68 major U.S. cities to currently be in excess of \$70 billion per year.

with service offerings. Knowledge of customer needs and expectations will be useful in benchmarking and developing meaningful performance measures.

2. Maximizing Efficiency and Minimizing Congestion

Although the physical condition of the nation's surface transportation systems has shown sustained improvement, the quality of service provided by these systems has clearly declined. This decline is most evident in the nation's urbanized regions. This theme includes all techniques used to address both recurring and nonrecurring congestion under all conditions and involves topics such as optimizing demand–supply relationships. The objectives are to identify opportunities for operational improvements through the coordinated application of supply-and-demand techniques and to develop new approaches that offer the promise for improved operational efficiency, as well as higher levels of staff productivity.

3. Information Needs and Requirements

More knowledge is needed as to what types of information different customers need and how that information can be effectively conveyed. Despite the revolution in information technologies, significant gaps still exist in identifying and satisfying the needs of the public and private sectors. Availability of personalized information for users is limited and frequently out of date. Information for system operators is limited, difficult to use, and inconsistently stored. Few provisions exist for sharing information across jurisdictional boundaries. The objective of this theme is the development of information collection, retrieval, and presentation techniques that will enhance transportation operations.

4. Transportation Safety

Although a separate working group is addressing safety, safety is such an integral part of operations that specific safety issues related to operations are included in this theme. For example, two of the major causes of fatalities, excess speed and crashes involving pedestrians, can be addressed through operational measures. Further, improved safety (such as reductions in the number of incidents) often results in a reduction in congestion as well as a reduction in secondary accidents. Existing knowledge of the relationship between safety and operations is incomplete. The objectives of this theme are to improve the understanding of the relationship between operations and safety and to explore the application of advanced operational techniques that offer the potential for improved safety.

5. Environmental Issues

Although a separate working group is addressing the environment, certain environmental concerns are closely linked to transportation operations and are included in this theme. Transportation operations can have an impact on air and water quality. Cleanup of hazardous material spills and maintenance can have significant environmental impacts. Transportation operations can also have an impact on public health and quality of life. The objectives of this theme include advancing the understanding of the impact of traffic operations on the environment, developing improved tools for quantifying emissions under varying traffic conditions, and measuring the impact of traffic conditions on localized environmental conditions.

6. Intermodal Interfaces and Efficiencies

Issues addressing the efficiency of intermodal interfaces, including topics such as just-in-time delivery and advanced information on the status of parking facilities, are included in

this theme. Transportation operations managers must recognize that mobility for travelers and goods is a multimodal consideration. The optimization of a single facility does not necessarily translate into the optimization of trips. Intermodal research focuses on optimizing the total trip for travelers. The objective of this theme is the development of an understanding of the relationship between intermodal interface operations and the efficiency of these connections. A second objective is to gain a better understanding of the impact of personal mobility and goods movement as a function of operational measure.

7. Research Programs and Processes

This theme is common to all of the working groups. It involves questions such as how will research topics be identified and prioritized; what stakeholders have an interest in the research topics; who will fund the research; who will perform the research; what can be done to increase the likelihood of implementing research; and so forth. Material presented in the Operations and Mobility Working Group paper suggests that only a modest amount of research is being performed in the transportation-operations area and that current research is not well coordinated. Because of a lack of coordination and prioritization, there is no doubt that duplicative studies are being pursued, and some areas of high national importance are not being properly addressed. Those who might be expected to use or implement the research may not be involved in the research process. It appears that opportunities exist to enhance the effectiveness of research through programmatic changes.

8. Crosscutting Issues

This theme includes issues such as performance measures, institutional and regulatory issues, training and education, and data needs.

Policy Analysis, Planning, and Systems Monitoring

The other working groups also dealt with planning and policy-related R&T issues within their respective areas. Also, planning as related to environmental concerns is being addressed by the Planning and Environment Working Group. There is, therefore, some overlap among the group reports, as identified in the section entitled “Crosscutting Concerns.”

For an outline of the themes and areas identified by the Policy Analysis, Planning, and Systems Monitoring Working Group, please see Table 7. The Policy Analysis, Planning, and Systems Monitoring Working Group identified four broad themes.

1. Improving Understanding of the Interactions Between Transportation and Society

What does the transportation community need to understand about how societal changes are affecting the demand for transportation and how transportation is serving social and economic health? The emerging interactions between transportation and society have at least three elements. These include the following:

- A changing demographic structure—including critical changes in the labor force;
- A changing economic structure—operating in a new world marketplace; and
- A changing technological structure—heavily linked to information technologies.

As the United States enters the new century, it faces dramatic changes in the nature of its population and its economy, changes in the world economic structure in which it competes, and changes in the technologies that will be employed. All of these forces of change will affect transportation both directly and indirectly and will affect how transportation interacts with society, the economy, and the environment.

Two other elements—safety and environment—are not covered here because they are covered by other working groups.

2. Enhancing Data-Driven Decisionmaking Tools

What analytical tools are needed for use in decision making regarding the understanding of transportation's interaction with society? The ability to make decisions about the transportation system requires understanding of what the system should do and what it does do. In order to set out a vision for the transportation system, an understanding of the impacts of the system on societal functions is necessary. Consequences need to be better understood, impacts analyzed, and alternatives evaluated. Given the nature of the highway funding environment, there is a continuing need for research into system finance to find better, more efficient, and more equitable means of meeting future highway funding needs. Extraordinary advances in technology have resulted in the ability of groups and individuals to collect, store, access, and interpret large amounts of data, thereby making it possible to develop and use advanced decisionmaking tools to address these concerns.

3. Improving Monitoring of Evolving Trends (Data, Analytical Tools, and Systems Monitoring)

What data need to be collected to help achieve an understanding of the transportation system and to support the decision tools, and how can accurate and timely data be obtained with minimal cost and burden? With passage of ISTEA and TEA-21, the number of stakeholders involved in the decisionmaking processes and the range of issues to address have grown significantly. Concerns such as air quality conformity, environmental justice, global warming, and sustainability have placed even greater demands on data needs and analytical requirements. Many of the tools and data sources currently in use were developed in an earlier era. Even though there has been progress in adapting these tools and data sources to current and future needs, there remain many shortcomings.

4. Advancing Multimodal Transportation Planning

The implications of federal transportation legislation and the shift of focus away from facility planning to policy development, system management, customer needs, and financing indicate the need for research in areas such as performance-based planning and alternative financing approaches. ISTEA and its regulations required states to develop and maintain their own transportation planning processes, and these requirements were revised in TEA-21. The planning processes that have evolved reflect the uniqueness of each state—the variation in statutory and institutional responsibilities, the size, the degree of urbanization, the growth rate, and other variables leading to the differences among states.

When the nation's increasing population and growing availability of cars and light trucks combine with the continually expanding boundaries of urban areas, the result is a collision course with sustainability.

Planning and Environment

This working group served a dual role—as one of the five working groups of the R&T Partnership and as the NRC Advisory Board on STECRP. The Advisory Board's final report, which describes detailed R&T needs and recommends a research program, will be published by the NRC. Please note that the cost estimate of \$150 million covers all surface transportation environmental R&T, including the proposed national cooperative program and ongoing programs of federal agencies such as U.S. EPA and U.S. DOT.

Table 8 includes the themes and emphasis areas identified by this working group. The group identified six themes.

1. Human Health

This theme focuses on transportation's impact on the environment and the resulting potentially adverse effects on human health. Historically, transportation's impact on air-quality standards and the effects of greenhouse gases such as carbon dioxide have been well documented, along with health effects resulting from lead exposure. As transportation planning has evolved and Americans' concern with the environment has risen, new areas such as water quality and safety have emerged as concerns for the transportation community. For example, Americans have expressed a desire for context-sensitive design and aesthetically pleasing roadways. Transportation professionals are increasingly being confronted with the mandate to protect and even enhance the environment while remaining cognizant of highway safety issues.

2. Ecology and Natural Systems

Historically, transportation's impact on the environment has been measured in terms of human health; consequently, issues such as air pollution have received considerable attention. However, little research has been performed on these same emissions to analyze their potential impacts on ecosystem health and, more particularly, on the long-term ecological consequences. In order to assess fully the inherent trade-offs between a clean environment and an efficient transportation system, both the transportation community and the American public need to understand the impacts of transportation on the environment in both the short and long term. For example, if key species are reduced or eliminated because of the impacts from a transportation project, to what extent will biodiversity be altered? This question can only be answered by long-term monitoring and evaluation of the ecosystem. Another example involves the use of wildlife plantings near highways to reduce maintenance or create aesthetically attractive roadsides, or both. To what extent will these plantings disrupt the natural environment or the functions provided by the ecosystem, or both?

3. Distributional Aspects

ISTEA mandated that transportation planners consider broader public-policy goals in the transportation planning process. These goals included improving the environment, the economy, and the ability to move people and goods in an energy-efficient manner. Inherent in this statement is the ability for transportation systems to provide equal access to all people and to consider the direct, secondary, and cumulative impacts of environmental-justice considerations in the transportation planning process. The question of whether

economic benefits realized from transportation investments are equitably distributed across a region must also be considered and factored into the transportation planning process.

4. Emerging Technologies

The transportation industry is on the cusp of a technological revolution. Specifically, the industry is expected to incorporate two largely new sets of technologies: (1) propulsion technologies and fuels that change the energy, pollution, and noise characteristics of vehicles and (2) information, communication, and control technologies that change how vehicles are used. How these paths might unfold and how public policy might influence their direction to achieve enhanced environmental quality are two critical research questions.

5. Land Use

The traditional debate between transportation and land use centers around the question of whether it is the built environment that influences travel behavior (e.g., how often and how far people are willing to walk, drive, or take public transportation) or, conversely, whether it is transportation that predicates land-use designations. To what extent can transportation investments alter development patterns? Empirical studies seem to indicate that transportation is not the primary impetus for new economic growth in a region, but that transportation does substantially contribute to a shift in economic-development growth patterns. The magnitude of this shift and its resulting effect, however, remains unclear. The connection between transportation and land use has risen in importance as urban sprawl and growth-management strategies become the topic for debate among environmentalists, transportation planners, and local and state legislatures.

6. Planning and Performance Measures

As espoused in ISTEA and TEA-21, the mission of today's transportation planners is to effectively balance the needs of transportation mobility with the broader societal goals of economic competitiveness and environmental sustainability. As the traditional transportation-planning process has evolved, so too must the supporting research. For example, in order to meet these new goals, transportation planners must develop mechanisms for ensuring that all interests are equitably involved in the planning process, particularly the interests of minorities and low-income populations. Research is needed to assist planners in assessing the effectiveness of various public-involvement processes and in establishing the link between public involvement and customer-based planning and the actual decisionmaking process. Transportation planners must also consider the ramifications of decisions to expand transportation systems to accommodate greater economic growth. To what degree are secondary and cumulative environmental impacts of system-level transportation decisions being considered in these decisions? Are transportation planners being provided with sufficient data to make well-informed recommendations? The first part of this theme addresses the issue of augmenting and refocusing the research currently available to transportation planners.

The second part of this theme focuses on the issue of performance measures and performance-based planning. In addition to the expansion of the scope of transportation planning, a movement has evolved to insert increased levels of accountability into the transportation-

planning process. How are transportation agencies factoring economic development and environmental sustainability into the transportation-planning process? How are these goals measured? What are the indicators for success? Specifically, transportation planners are increasingly expected to develop goals that are measurable and to report on their progress in meeting these goals. Planners are being advised that it is no longer acceptable to measure the progress of a single mode—rather, it is the total system’s performance that will be measured and evaluated. In a relatively short period of time, the expectations for the transportation-planning process have altered significantly.

Crosscutting Concerns

Although each working group had been assigned a specific area of interest, it was clear that some potential overlap existed. To not unduly restrict each group’s scope, it was decided to have each group work within its broad area without concern for overlap or duplication. As a result, readers interested in a particular topic should recognize that the report may include information on this topic in more than one section. Table 9 identifies the most common crosscutting concerns and locates the related text in each individual working group report. It should be noted that these concerns are not necessarily more important than others simply because they are crosscutting; their crosscutting nature attests to the breadth of these concerns rather than to their relative importance to other concerns. In addition to the crosscutting concerns that follow, the working groups indicated that customer service, implementation, and promotion and delivery of innovation were also of great concern, even though they were not included by more than one group as an R&T need.

Highway Safety

Not surprisingly, various aspects of highway safety were addressed in all working groups. The Safety Working Group focused on R&T needs not directly related to specific safety aspects of a particular discipline (e.g., construction). The previous caution regarding presumptions on priorities and relative importance notwithstanding, it is clear that safety has been and will continue to be a high priority for the highway community. Considerable success has been achieved, especially in view of the significant increases in travel demand, but there is much more that needs to be done.

Environment

Environmental concerns are almost as broadly based as are safety concerns. Few aspects of highway transportation do not have a direct or indirect effect on the environment. From environmental regulations affecting major project approvals to water runoff concerns when replacing a small culvert, transportation and the environment are inseparably linked.

Planning

By its basic nature, planning cuts across many aspects of transportation. Planning is fundamental to policy initiatives, safety programs, highway location studies, and congestion mitigation measures, to name a few aspects.

Information and Data

The need for better information and data to support all aspects of highway transportation is evident throughout the working group reports, both through direct recognition and by implication. Ranging from better information on which to base national policy

decisions to improved data to ascertain the infrastructure condition to more accurate statistics on driver behavior, adequate resources for the collection and management of information are of critical concern.

Transportation Security

The working groups' reports were prepared before the recent emphasis on security resulting from the national tragedy of September 11, 2001. Although the reports do not contain specific references to such national disasters, some of the identified R&T pertains directly to such events. For examples, please see Table 9.

Performance Measures

Providers of highway facilities have an increasing desire to assess system performance in order to ensure maximum payoffs from investments. Many state DOTs have established such assessment systems, often with questions regarding what factors are to be used in making quantitative or qualitative assessments, or both. Beyond the question of "what" is the question of "how": how can the supporting data for these measures be accurately collected and analyzed?

Workforce Training

Widespread concern exists related to the development of a workforce of sufficient size and with appropriate training to address current needs. Large-scale retirements from state DOTs, as well as from other organizations, following the Interstate era severely reduced the availability of an experienced workforce. Further, the changing nature of highway development, such as multidisciplinary teams and automated systems, calls for a different mix in the workforce, which heretofore consisted largely of civil engineers. The working groups clearly identified workforce concerns as a major issue.

MANAGING THE R&T PROCESS

All working groups were asked to comment on potential improvements to the way in which R&T programs are currently developed and conducted, particularly in relation to partnerships. Each paper addresses this question to some extent, and the Safety Working Group outlined a conceptual process. With safety having such wide importance in many areas and with numerous sponsors involved in conducting safety R&T, it is not surprising that the safety community saw improved coordination and cooperation as a special need.

The Safety Working Group identified the following potential outcomes from an improved research, development, and implementation process:

- Focused and integrated research efforts;
 - Resources targeted to areas that have the greatest potential for improving safety;
 - Increased formal collaboration and coordination among federal, state, university, and private research organizations;
 - Increased opportunities for developing an integrated approach to the crash problem;
 - Increased input from end users;
 - Increased consideration and development of implementation strategies throughout the research process; and
 - Increased efficiency, speed, and effectiveness of implementation of safety innovations.
-

Three stages are proposed for the process:

1. *Formulating* annual and long-term research budgets and programs;
2. *Conducting* the actual research and creating new knowledge; and
3. *Implementing* research results to reduce crashes, injuries, and deaths.

The proposed process calls for an annual meeting with the involvement of all parties in the discussion of critical R&T needs and opportunities to integrate joint efforts. The process also encourages sponsors to (1) develop or improve a quality-assurance process to enhance program effectiveness, (2) view the development of an implementation plan as an integral part of the research project, and (3) improve the reporting and dissemination of findings.

Presumably, further discussion of this general conceptual research process will take place at future forums of the partnership. Potential application in the highway safety community, as well as in the broader highway community, should be considered. Readers are urged to read the full section in the Safety Working Group paper (www.trb.org).

The call for an improved R&T process should not be construed as an indication that cooperation and coordination among highway R&T sponsors is nonexistent. In fact, much time and effort is taken to share information regarding the various programs, both in developing and in conducting the R&T. Many of these coordination efforts are institutionalized (e.g., FHWA participation with AASHTO's SCOR in the development of NCHRP), while others are ad hoc (e.g., presentations on planned programs at national conferences). Nonetheless, a desire shared by all parties is to ensure that the numerous program development efforts are sufficiently coordinated to make the best use of limited funds.

4

NEXT STEPS

To conduct a comprehensive R&T program within a decentralized community, the need for coordination and partnerships is clear. The first step is to involve the broad community in the initial determination of needs. To that end, the National Highway R&T Partnership involved an unprecedented number of individuals and organizations in its outreach. The R&T themes identified herein present the perspectives of most of the many players within the highway community. As a result, research sponsors have the assurance that, although not based on a rigorous consensus-building process, the findings are relevant to the current challenges faced by practitioners.

POTENTIAL USES OF THIS REPORT

Sponsors of Highway R&T Programs

Federal agencies, including FHWA, FMCSA, NHTSA, FTA, the U.S. EPA, and others, can draw from this report as they develop their annual or long-term R&T programs. The working group reports, in particular, offer supporting information for funding R&T within each theme and identify many specific emphasis areas considered to be of high priority. This report, along with the related efforts described previously, should provide a sound foundation for program development.

AASHTO, through SCOR, plans to use the R&T needs identified by the partnership's working groups to develop an AASHTO R&T plan to be carried out under the next federal-aid highway reauthorization. State DOTs can draw from this report, along with the individual working group reports, in determining R&T needs that should be forwarded to SCOR for consideration in NCHRP. States may also decide to conduct some of the identified R&T within their own state research programs.

Related Activities

The findings of the partnership will be useful to other initiatives that are being conducted to identify national highway R&T needs. These other initiatives are described in the Introduction under "Related Activities."

- RTCC considered this report as it developed recommendations related to the federal role in highway research. The RTCC report has been published as *TRB Special Report 261: The Federal Role in Highway Research and Technology*.
- F-SHRP reviewed the partnership's reports as part of its effort to determine R&T priorities for a new national program. F-SHRP completed its work in October 2001,

and the final report has been published as *TRB Special Report 260: Strategic Highway Research—Saving Lives, Reducing Congestion, Improving Quality of Life*.

- STECRP, which is also serving a dual role as one of the five partnership working groups, will benefit from input by the other working groups as it develops the national agenda for energy, environment, and planning research. STECRP will complete its task by mid-2002.
- Initiatives by other organizations, such as ITS America, will also find the partnership reports useful as they develop R&T needs within their particular areas of concern.

THE PARTNERSHIP'S FUTURE

The partnership met on August 14, 2001, to review and finalize this report, which summarizes the effort to date, and to determine any further activities for the partnership. The participants decided that the partnership initiative should be continued, and the next meeting is planned for mid-2002. Individuals or organizations wishing to participate should contact Mark Norman at TRB (mnorman@nas.edu).

Tables

TABLE 1 R&T themes and costs

<i>WORKING GROUP</i>	<i>THEMES</i>	<i>ANNUAL COSTS (millions of \$)</i>	<i>TIME PERIOD (years)</i>
Safety	1. Safety Management and Data Systems	10	5
	2. Driver Competency	20	5
	3. High-Risk Driving	40	5
	4. Light-Duty Vehicle Safety	20	5
	5. Highway Infrastructure and Operations	30	5
	6. Vulnerable Road Users	10	5
	7. Heavy Truck and Bus Safety	10	5
	8. Post-Crash Management	10	5
		<i>SUBTOTAL</i>	<i>150</i>
Infrastructure Renewal—Asset Management	1. Information Management	5	10
	2. Decision Support Tools	5	5
	3. Implementation	1	3
	4. Education	2	10
Infrastructure Renewal—Pavements	1. Designs and Materials	50	6–8
	2. Construction and Maintenance Techniques and Technologies	50	6–8
	3. Safer, Environmentally Friendly Pavements	10	6
	4. Education, Communication, and Job Training	25	6
	5. Promotion and Delivery of Innovation	25	6
Infrastructure Renewal—Highway Structures	1. Enhanced Materials, Structural Systems, and Technologies	15	5
	2. Efficient Maintenance, Rehabilitation, and Construction	10	5
	3. Safety Assurance of Highway Structures for Extreme Events	15	5
	4. Assessment and Management of Bridges and Other Structures	10	5
	5. Enhanced Specifications for Improved Structural Performance	10	5
	6. Information and Automation for Structure Design, Construction, and Maintenance	10	5
	<i>SUBTOTAL</i>	<i>243</i>	

(continued)

TABLE 1 R&T themes and costs (continued)

WORKING GROUP	THEMES	ANNUAL COSTS (millions of \$)	TIME PERIOD (years)
Operations and Mobility	1. Customers, Customer Expectations, and Customer Needs	6	5
	2. Maximizing Efficiency and Minimizing Congestion	48	5
	3. Information Needs and Requirements	12	5
	4. Transportation Safety	12	5
	5. Environmental Issues	6	5
	6. Intermodal Interfaces and Efficiencies	18	5
	7. Research Program and Process	–	–
	8. Crosscutting Issues	18	5
		<i>SUBTOTAL</i>	<i>120</i>
Policy Analysis, Planning, and Systems Monitoring	1. Improving Understanding of the Interactions Between Transportation and Society	4	5–10
	2. Enhancing Data-Driven Decisionmaking Tools	7	5–10
	3. Improving Monitoring of Evolving Trends	13	Continuing
	4. Advancing Multimodal Transportation Planning	42	3–10
		<i>SUBTOTAL</i>	<i>66</i>
Planning and Environment	1. Human Health	*	
	2. Ecology and Natural Systems		
	3. Distributional Aspects		
	4. Emerging Technologies		
	5. Land Use		
	6. Planning and Performance Measures		
		<i>SUBTOTAL</i>	<i>150</i>

* The Planning and Environment Working Group did not breakdown specific costs for each theme.

TABLE 2 R&T themes and emphasis areas—Safety

<i>THEME</i>	<i>EMPHASIS AREAS</i>
1. Safety Management and Data Systems	<ul style="list-style-type: none"> ■ Recommendations for implementing research and evaluation results ■ Case studies and guidelines for safety management practices and principles ■ Collection, management, and analysis of crash data ■ Crash causation research
2. Driver Competency	<ul style="list-style-type: none"> ■ Novice drivers ■ Countermeasures for managing inattention ■ Safe mobility for older drivers ■ Learning opportunities and resources to improve driver skills
3. High-Risk Driving	<ul style="list-style-type: none"> ■ Impaired driving by targeted drivers (e.g., high blood-alcohol content) ■ Child and adult restraint use ■ Automated enforcement equipment ■ Drivers without licenses or with revoked licenses ■ Aggressive driving ■ Understanding of risk-taking characteristics
4. Light-Duty Vehicle Safety	<ul style="list-style-type: none"> ■ Crash avoidance capabilities—vehicle handling and stability, braking and traction control, conspicuity, lighting, and signaling ■ Human-machine interface in light-duty vehicles ■ Restraint system designs and passenger compartment integrity ■ Vehicle compatibility ■ Biomechanics evaluation protocols and crash dummies ■ Driver fitness monitoring technology ■ Child safety ■ Performance of vehicles
5. Highway Infrastructure and Operations	<ul style="list-style-type: none"> ■ Human factor safety guidelines ■ Consequences of leaving the road ■ Intersection safety ■ Intelligent infrastructure initiative ■ Work zones ■ Inclusion of safety in the highway design process
6. Vulnerable Road Users	<ul style="list-style-type: none"> ■ Crash and use data regarding walking, bicycling, and motorcycling ■ Safer road sharing for pedestrians and bicyclists ■ Off-road facilities for pedestrians and bicyclists ■ Visibility and conspicuity ■ Educational materials

(continued)

TABLE 2 R&T themes and emphasis areas—Safety (*continued*)

THEME	EMPHASIS AREAS
7. Heavy Truck and Bus Safety	<ul style="list-style-type: none"> ■ Truck and bus crashes and their precursors ■ Driver errors ■ Heavy-vehicle safety equipment and technologies ■ Enforcement of commercial motor carrier safety regulations ■ High-risk carriers and drivers ■ Commercial driver training and performance management ■ Driver alertness and fatigue management ■ Driver physical and medical fitness ■ Highway infrastructure and operations
8. Post-Crash Management	<ul style="list-style-type: none"> ■ Emergency medical systems interventions for motor vehicle crash victims ■ Trauma system effectiveness ■ Interventions and technologies ■ Intelligent vehicle systems ■ Simulated patient training using emerging electronic technology

TABLE 3 R&T themes and emphasis areas—Infrastructure Renewal (Asset Management)

<i>THEME</i>	<i>EMPHASIS AREAS</i>
1. Information Management	<ul style="list-style-type: none"> ■ Data systems integration ■ Legacy systems preservation ■ Data standards for measurement, accuracy, and precision
2. Decision Support Tools	<ul style="list-style-type: none"> ■ Probabilistic life-cycle scenario analysis ■ Valuation analysis (inherent value of an asset and the economic value of mobility benefits) ■ Benefits determination ■ Performance measures for integrating customer and organizational goals ■ Presentation of asset management results
3. Implementation	<ul style="list-style-type: none"> ■ Organizational commitment ■ Barriers to implementation
4. Education	<ul style="list-style-type: none"> ■ Operational training for collecting and managing data, applying analytical tools, and interpreting and presenting the results ■ Organizational training for a broad spectrum of functions and levels ■ Outreach (awareness) training

TABLE 4 R&T themes and emphasis areas—Infrastructure Renewal (Pavements)

<i>THEME</i>	<i>EMPHASIS AREAS</i>
1. Designs and Materials	<ul style="list-style-type: none"> ■ Prediction and measurement of pavement performance ■ Quantification of total life-cycle costs ■ Long-term durability of paving materials—aggregates, binders, and admixtures and additives
2. Construction and Maintenance Techniques and Technologies	<ul style="list-style-type: none"> ■ Road user cost data for traffic congestion and delays ■ Impact of nontraditional contracting practices on construction time ■ Long-term durability of construction materials ■ Specialized construction and nondestructive testing equipment
3. Safer, Environmentally Friendly Pavements	<ul style="list-style-type: none"> ■ Long-term performance of recycled pavement materials ■ Pavement surface properties and characteristics related to noise, safety, and vehicle–pavement interaction
4. Education, Communication, and Job Training	<ul style="list-style-type: none"> ■ Existing and new educational program improvements ■ Deployment of new technologies into research efforts
5. Promotion and Delivery of Innovation	<ul style="list-style-type: none"> ■ Converting research results into implementable products ■ Management techniques for product delivery

TABLE 5 R&T themes and emphasis areas—Infrastructure Renewal (Highway Structures)

THEME	EMPHASIS AREAS
1. Enhanced Materials, Structural Systems, and Technologies	<ul style="list-style-type: none"> ■ Fiber-reinforced polymer composites ■ High-performance concrete and steel ■ Advanced corrosion protection systems
2. Efficient Maintenance, Rehabilitation, and Construction	<ul style="list-style-type: none"> ■ Cost benefits of design–build approach ■ Maintenance outsourcing and contract maintenance ■ Cost benefits of preventive maintenance ■ Life-cycle costs of innovative prefabricated systems
3. Safety Assurance of Highway Structures for Extreme Events	<ul style="list-style-type: none"> ■ Acceptable risk under extreme events ■ Bridge instrumentation program implementation ■ Structure performance specifications
4. Assessment and Management of Bridges and Other Structures	<ul style="list-style-type: none"> ■ Enhancements such as the inclusion of geographical information systems data ■ Adaptation of bridge management system frameworks for structures other than bridges ■ Nondestructive testing technologies ■ Databases to support bridge management systems ■ Risk management and capital investment strategies
5. Enhanced Specifications for Improved Structural Performance	<ul style="list-style-type: none"> ■ High-performance materials specifications ■ Fiber-reinforced polymer composite materials specifications ■ Rapid replacement and repair specifications ■ Specifications for structures other than bridges and for other transportation modes ■ Load resistance factor design–based geotechnical engineering research and validation studies
6. Information and Automation for Structures Design, Construction, and Maintenance	<ul style="list-style-type: none"> ■ Computer-integrated management system for bid estimating, project management, and construction ■ Computer-integrated/automated project delivery system ■ Data to link related design components ■ Protocols for storing and managing project data ■ Interactive Internet modules related to load and resistance factor design, bridge management systems, and inspection ■ Protocols for online access to AASHTO specifications and transportation guides ■ Automation support of design and analysis tools ■ Software verification/validation

TABLE 6 R&T themes and emphasis areas—Operations and Mobility

<i>THEME</i>	<i>EMPHASIS AREAS</i>
1. Customers, Customer Expectations, and Customer Needs	<ul style="list-style-type: none"> ■ Customer expectations ■ Impacts of competing services ■ Systems operations warrants ■ Performance measures ■ Training in meeting customer needs
2. Maximizing Efficiency and Minimizing Congestion	<ul style="list-style-type: none"> ■ Performance objectives ■ Impact of operations on the behavior of travelers ■ Evaluating performance ■ Predictive transportation management ■ Monitoring facility performance ■ Operational management ■ Incident management ■ Personnel and agency organization ■ Interagency relationships and regional transportation management ■ Work zone and social events management ■ Weather response ■ Travel demand management ■ Legal and regulatory barriers ■ Trade-offs between operational and infrastructure improvements ■ Relationships between transportation management and alternate modes of transportation
3. Information Needs and Requirements	<ul style="list-style-type: none"> ■ Information requirements of users ■ Relationship between information and traveler behavior ■ Data needs of agency personnel ■ Low-cost data collection techniques ■ Rural characteristics and information needs ■ Institutional issues associated with data sharing ■ Information presentation needs of disabled travelers
4. Transportation Safety	<ul style="list-style-type: none"> ■ Strategies for incident response ■ Advanced technology applications ■ Grade crossing and work zone safety ■ Photo enforcement ■ Combination of enforcement with improved operations ■ Communication of successful practices ■ Pedestrian safety ■ Speed regulation

(continued)

TABLE 6 R&T themes and emphasis areas—Operations and Mobility
(continued)

THEME	EMPHASIS AREAS
5. Environmental Issues	<ul style="list-style-type: none"> ■ Environmental science ■ Analysis tools ■ Impacts of operational measures ■ Best practices ■ Relationship between operations and the environment of neighborhoods and communities
6. Intermodal Interfaces and Efficiencies	<ul style="list-style-type: none"> ■ Goods movement ■ Supply-chain management concepts ■ Impact of teletravel on access to services and transportation mobility ■ Institutional and cultural response to increased emphasis on operations
7. Research Programs and Processes	<ul style="list-style-type: none"> ■ None
8. Crosscutting Issues	<ul style="list-style-type: none"> ■ Performance measures ■ Institutional and regulatory issues ■ Training and education ■ Data needs

TABLE 7 R&T themes and emphasis areas—Policy Analysis, Planning, and Systems Monitoring

<i>THEME</i>	<i>EMPHASIS AREAS</i>
1. Improving Understanding of the Interactions Between Transportation and Society	<ul style="list-style-type: none"> ■ Demographic interactions ■ Economic interactions ■ Technology interactions
2. Enhancing Data-Driven Decisionmaking Tools	<ul style="list-style-type: none"> ■ Linkage between investment and benefits ■ Performance measures ■ Innovative financing approaches ■ Alternative revenue and tax sources ■ Traditional highway user funding ■ Public-private partnerships
3. Improving Monitoring of Evolving Trends	<ul style="list-style-type: none"> ■ Sustainable data collection ■ More responsive analytical tools ■ Continuing, coordinated, comprehensive system monitoring
4. Advancing Multimodal Transportation Planning	<ul style="list-style-type: none"> ■ Performance-based planning ■ Collaborative planning and partnerships ■ Management and operations ■ Planning and programming ■ Multimodal and intermodal planning ■ Goods movement planning ■ Technology ■ Environment and sustainability

TABLE 8 R&T themes and emphasis areas—Planning and Environment

<i>THEME</i>	<i>EMPHASIS AREAS</i>
1. Human Health	<ul style="list-style-type: none"> ■ Modal emissions ■ Vehicle emissions and toxic pollutants ■ Air-quality models ■ Toxicity of road dust ■ Epidemiology of air pollution ■ Preferences for improved health ■ Cost-effectiveness, cost-benefit analysis ■ Transportation-related noise
2. Ecology and Natural Systems	<ul style="list-style-type: none"> ■ Roadside design and maintenance ■ Wildlife movements and crossings ■ Road effects on adjoining land ■ Ecologically optimum road network models ■ Landscape-wide environmental analysis and road-effect zone models ■ Hydrologic and sediment flows and distributions ■ Water quality and aquatic ecosystems ■ Ecological effects of air pollutants
3. Distributional Aspects	<ul style="list-style-type: none"> ■ Transportation investment disparities ■ Economically disadvantaged communities ■ Transportation-disadvantaged communities ■ Environmental justice and distributional impacts (performance measures) ■ Transit investment disparities ■ New approaches to social justice attributes ■ Citizen coalitions in environmental justice
4. Emerging Technologies	<ul style="list-style-type: none"> ■ Fuel and propulsion technologies ■ Intelligent transportation technologies ■ User behavior and consumer choice ■ Policy instruments related to evolving technologies ■ Research and development institutional arrangements
5. Land Use	<ul style="list-style-type: none"> ■ Neighborhood and household location characteristics and travel behavior ■ Impact of transportation facilities on travel behavior ■ Impact on land use, development, and community ■ Benefits and causes of sprawl ■ Factors influencing driving and travel behavior ■ Limiting auto use and containing sprawl ■ Alternative policy and investment scenarios ■ Regional cooperation ■ Accessible tools

(continued)

TABLE 8 R&T themes and emphasis areas—Planning and Environment
(continued)

<i>THEME</i>	<i>EMPHASIS AREAS</i>
6. Planning and Performance Measures	<ul style="list-style-type: none"> ■ User perceptions and priorities ■ Personal travel behavior ■ Commercial travel and freight industry ■ Role of transportation in the economy, culture, and society ■ Community aspirations and vision ■ Tools on travel dynamics ■ Public policy and performance measures ■ Performance-based planning and decision making ■ Integration of planning, programming, design, and operations

TABLE 9 Crosscutting topics

TOPIC	WORKING GROUP	THEME OR EMPHASIS AREA	PAGE (working group report)	
Highway Safety	Safety	All	Entire report	
	Infrastructure	Work zone safety	22	
		Safer pavements	25	
		Safety assurance of structures	35	
		Operations	Incident management	23
			Work zone management	23
			Advanced technologies	28
			Grade crossings	28
		Enforcement	28	
	Pedestrians	29		
Environment	Infrastructure	Environmentally friendly pavements	25	
		Operations	Environmental issues	31
	Policy	Weather response	24	
		Analytical tools	23	
		Systems monitoring	26	
	Planning and Environment	Partnerships	18	
		Goods movement	na	
		Environment and sustainability	na	
		All	Entire report	
	Planning	Safety	Safety management and data systems	A-1
Off-road facilities for pedestrians and bicyclists			A-51	
Infrastructure		Information management	9	
		Decision support tools	11	
		Less disruptive construction and maintenance	22	
		Cost benefits of design–build approach	33	
		Cost benefits of preventive maintenance	34	
		Bridge management systems	36	
Policy		All	Entire report	
Planning and Environment		All	Entire report	
Information and Data	Safety	Safety management and data systems	A-1	
		Crash data for vulnerable road users	A-49	
	Infrastructure	Information management	9	
		Training for collecting and managing data	15	
		Road user cost data	22	
		Information and automation for structures	39	
		Operations	User information needs	25
	Policy	Technology interactions	10	
		Innovative finance	17	
	Planning and Environment	Sustainable data collection	21	
Emissions and air-quality models		na		

(continued)

TABLE 9 Crosscutting topics (continued)

TOPIC	WORKING GROUP	THEME OR EMPHASIS AREA	PAGE (working group report)
Transportation Security	Safety	Intelligent infrastructure initiative	A-43
		Post-crash management	A-70
	Infrastructure Operations	Safety assurance of structures	35
		Incident management	23
		Incident response	28
Performance Measures	Infrastructure	Integrating customer and organizational goals	12
		Pavement performance	21
	Operations	Performance of operational activities	21
		User and community goals	22
		Cost-effectiveness of performance measuring systems	23
	Policy	Monitoring facility performance	23
		Performance measures	17
		Performance-based planning	na
	Planning and Environment	Multimodal and intermodal planning	na
		Environmental justice and distributional impacts	na
Workforce Training	Infrastructure	Performance-based planning and decisionmaking	na
		Asset management	15
	Operations	Educational programs—pavements	26
		Meeting customer needs	21
		Safety	Driver skills
		Driver-fitness monitoring	A-32