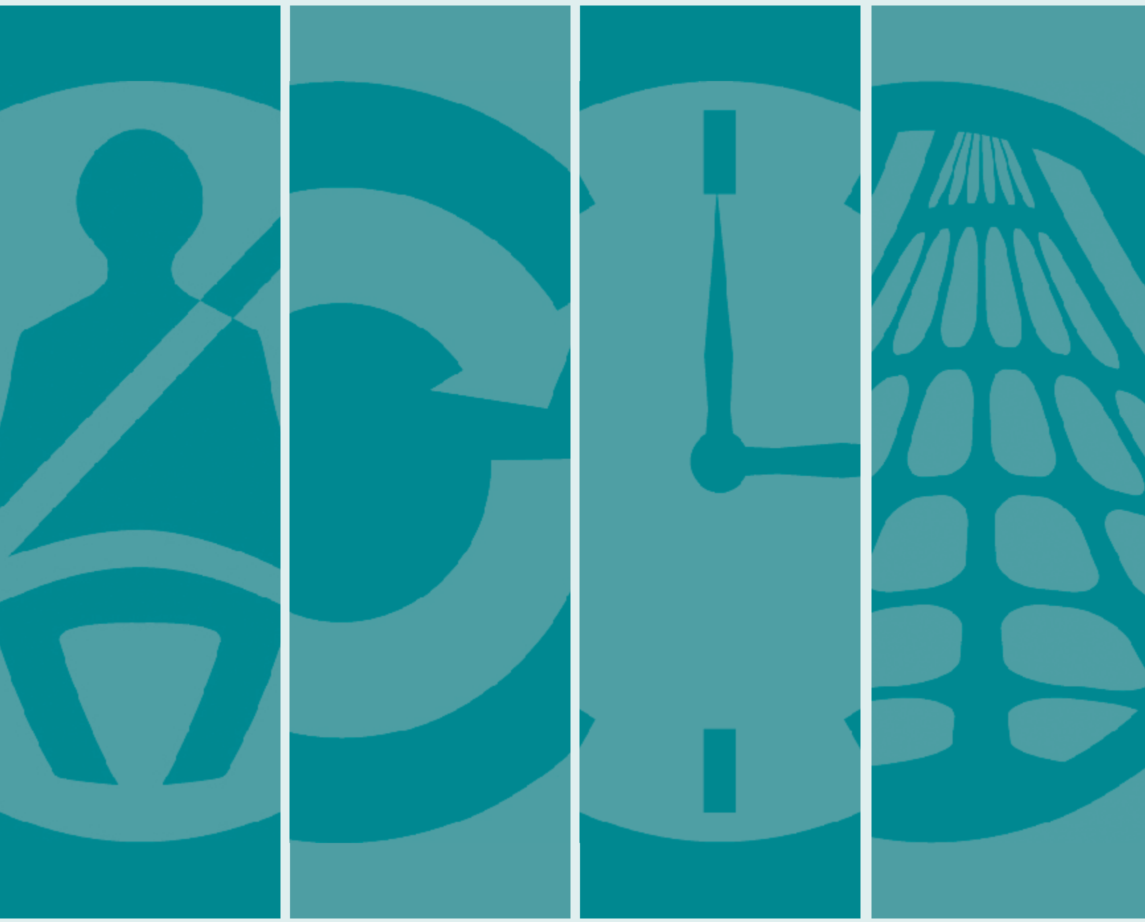
SPECIAL REPORT 296

Implementing the Results of the Second Strategic Highway Research Program

Saving Lives, Reducing Congestion, Improving Quality of Life



TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

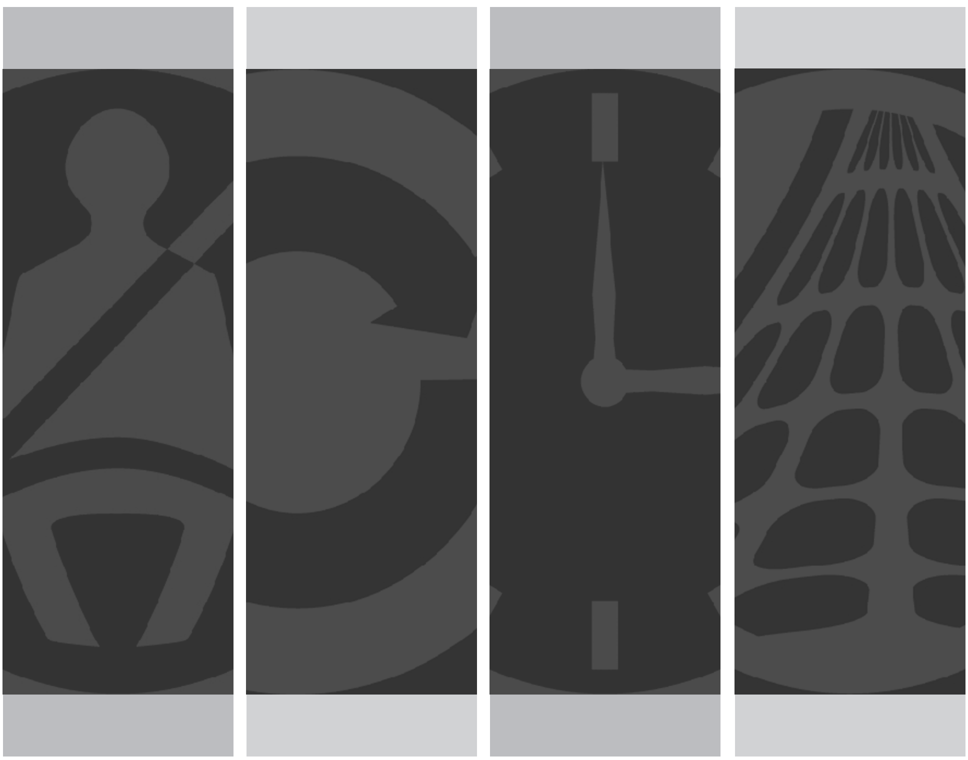
SPECIAL REPORT 296

Implementing the Results of the Second Strategic Highway Research Program

Saving Lives, Reducing Congestion, Improving Quality of Life

COMMITTEE FOR THE STRATEGIC HIGHWAY RESEARCH
PROGRAM 2: IMPLEMENTATION

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES



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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

In July 2005, the United States Congress passed the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This bill, which reauthorized the federal-aid highway program, established the second Strategic Highway Research Program (SHRP 2), which is currently being managed by the National Research Council's Transportation Research Board (TRB). SAFETEA-LU also called for TRB to "complete a report on the strategies and administrative structure to be used for implementation of the results" of SHRP 2. The congressionally mandated report, due to Congress no later than February 1, 2009, was to include the following:

> (A) an identification of the most promising results of research under the program (including the persons most likely to use the results); (B) a discussion of potential incentives for, impediments to, and methods of, implementing those results; (C) an estimate of costs of implementation of those results; and (D) recommendations on methods by which implementation of those results should be conducted, coordinated, and supported in future years, including a discussion of the administrative structure and organization best suited to carry out those recommendations. . . . in developing the report, the Transportation Research Board shall consult with a wide variety of stakeholders, including (A) the Federal Highway Administration; (B) the National Highway Traffic Safety Administration; and (C) the American Association of State Highway and Transportation Officials.[1]

To carry out this congressional request, TRB established a committee of leaders from the highway community, chaired by Kirk T. Steudle, Director of the Michigan Department of Transportation. The primary task of the

[1] SAFETEA-LU, Public Law 109-59, Section 5210, "Future Strategic Highway Research Program." The bill was signed into law on August 10, 2005.

Committee for the Strategic Highway Research Program 2: Implementation was to recommend approaches to implementing the results of SHRP 2 research;[2] therefore, the committee members were chosen for their demonstrated knowledge of the program, their expertise in research management and implementation, and their ability to represent major potential user groups. Brief biographies of the committee members are given at the end of this report. The committee also benefited from the contributions of liaisons from the American Association of State Highway and Transportation Officials, the Federal Highway Administration, and the National Highway Traffic Safety Administration, who coordinated the committee's work with their organizations and facilitated outreach to their colleagues throughout the study.

The due date for this report was set as February 1, 2009, at a time when it was believed that SHRP 2 would be authorized in October 2003. In the end, the legislation did not pass until August 2005, and the funding for the program did not become available until March 2006; thus the program began more than 2 years later than originally planned. Requests for proposals for the first set of research projects were advertised in July 2006, and researchers were chosen by the end of the year. The first contracts were signed in February 2007, and this committee began its work in December of that year. Although a number of interim reports and provisional results have been produced to date, no final product is actually ready for use. Nonetheless, the due date for this implementation report remained the same so that Congress would have the report in hand when it developed the next surface transportation authorization (due in October 2009). If the report had been submitted later, Congress would not have had the opportunity to act on its recommendations.

The committee conducted three meetings, in December 2007 and in June and October 2008, and a conference call in March 2008. The study was carried out in close cooperation with the SHRP 2 Oversight Committee and the four Technical Coordinating Committees (TCCs) that oversee the research being conducted in the four SHRP 2 focus areas. Two members of the Oversight Committee and one member from each of the TCCs

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[2] The scope of the committee's task did not include commenting on the content of the research program.

served on the report committee. Rosters of the Oversight Committee and the TCCs are provided in Appendix A.

The study was conducted under the overall supervision of Ann M. Brach, Deputy Director of SHRP 2. Portions of the report were written by Dr. Brach, Neil Hawks, Walter Diewald, Stephen Andrle, and James Bryant under the direction of the committee. Patricia Williams provided administrative support.

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

Appreciation is expressed to the following individuals for their review of this report: E. Dean Carlson, Carlson Associates, Topeka, Kansas; A. Ray Chamberlain, Fort Collins, Colorado; Irwin Feller, American Association for the Advancement of Science, Washington, D.C.; Ann Flemer, Metropolitan Transportation Commission, Oakland, California; Gary Hoffman, Harrisburg, Pennsylvania; John M. Mason, Jr., Auburn University, Auburn, Alabama; and Thomas B. Sheridan, Massachusetts Institute of Technology (emeritus), Newton. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the report's findings and conclusions, nor did they see the final draft before its release.

The review of this report was overseen by William Agnew, General Motors Corporation (retired), and H. Gerard Schwartz, St. Louis, Missouri. Appointed by NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. Rona Briere edited the report, and Alisa Decatur

provided word processing support for preparing the final manuscript. In the TRB Publications Office, Jennifer J. Weeks formatted the prepublication edition for posting to the TRB website; Norman Solomon provided final editorial guidance; and Juanita Green managed the book design and production, under the supervision of Javy Awan, Director of Publications.

Acronyms

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
CDMF	Collaborative Decision-Making Framework
CSS	context-sensitive solutions
DOT	department of transportation
EMS	emergency medical services
ETG	Expert Task Group
FHWA	Federal Highway Administration
FOT	field operational test
FY	fiscal year
GPS	Global Positioning System
HCM	*Highway Capacity Manual*
HOT	high-occupancy toll
IDEA	Ideas Deserving Exploratory Analysis
IRB	institutional review board
IT	information technology
ITE	Institute of Transportation Engineers
KDP	key decision point
LTAP	Local Technical Assistance Program
LTPP	Long-Term Pavement Performance
MOU	memorandum of understanding
MPO	metropolitan planning organization
NCHRP	National Cooperative Highway Research Program
NDE	nondestructive evaluation
NDS	naturalistic driving study

NEPA	National Environmental Policy Act
NHI	National Highway Institute
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
RFP	request for proposals
ROW	right-of-way
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SHRP, SHRP 1	First Strategic Highway Research Program
SHRP 2	Second Strategic Highway Research Program
SHSP	Strategic Highway Safety Plan
TCC	Technical Coordinating Committee
TIG	Technology Implementation Group
TRB	Transportation Research Board
TTR	travel time reliability
USDOT	U.S. Department of Transportation
UTC	University Transportation Center
VMT	vehicle miles traveled

Contents

Appendices

Summary

The highway system has a pervasive presence in U.S. society. Whether driving, biking, or traveling by bus, many Americans use the nation's roads every day in their personal, professional, family, and social activities. The 4-million-mile highway system is the backbone of the U.S. economy, carrying 65 percent of the nation's $15 trillion in freight traffic and 88 percent of all noncommercial person miles traveled. The highway network also provides passenger and freight links to all other modes of transportation.

U.S. highway facilities have been in constant use for decades, often exceeding their original design life and traffic volumes. As a result, the system is deteriorating and heavily congested. Moreover, deaths and injuries from highway crashes constitute a major public health concern. A few statistics suggest the scale of the issues and the importance of addressing them:

• Some 43,000 deaths and millions of injuries occur on the nation's roads every year; beyond the personal toll, the estimated annual cost of these deaths and injuries is $230 billion. After years of decline, the number of fatalities and the fatality rate per million vehicle miles traveled (VMT) appear to be leveling off. Safety professionals are increasingly convinced that substantial advances in the future must be based on a fuller understanding of the most critical and least examined component of the driving system—the driver.

• In 1999, resurfacing was performed on 12.85 percent (20,586 miles) of the National Highway System. Reconstruction was performed on 3,200 miles of roads. The average age of bridges in the national inventory is 40 years; 27.5 percent of this inventory is structurally deficient or functionally obsolete. Work zones appear to be ubiquitous, causing disruption, delays, and unsafe conditions.

• In 2005, congestion cost travelers more than 4.2 billion hours and nearly $80 billion and resulted in the waste of approximately 3 billion gallons of fuel. One of the most significant impacts of congestion on the individual driver is the increasing difficulty of predicting how long a given trip will take. This lack of travel time reliability has both personal and economic costs.

• By 2030, the U.S. population is expected to grow by 24 percent, VMT by 60 percent, and truck VMT by 75 percent; truckloads are predicted to increase by 80 percent, to nearly 23 billion tons, by 2035. In addition to better system operation and more rapid renewal of in-place infrastructure, this growth will necessitate additional highway capacity in selected locations. Any capacity enhancements will have to be performance driven and outcome based while integrating environmental, economic, and community requirements.

THE SECOND STRATEGIC HIGHWAY RESEARCH PROGRAM

Research and innovation have an important role to play in addressing the issues and concerns associated with the planning, design, building, maintenance, operation, and use of the highway system. In addition to ongoing research programs at the federal and state levels, in private industry, and at universities, strategic research programs have focused on particular critical needs. These include the American Association of State Highway Officials Road Test, conducted in the late 1950s, and the first Strategic Highway Research Program (SHRP 1), conducted in the late 1980s and early 1990s.

The success of SHRP 1 prompted Congress to authorize a second Strategic Highway Research Program (SHRP 2) in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005. Approximately $170 million is expected to be appropriated over a 4-year period (2005–2009) to support a program lasting 7 years (mid-2006 to mid-2013). The content of the program was specified to include four research focus areas:

• *Safety:* Make a significant improvement in highway safety. The overall goal of this research is to prevent or reduce the severity of highway crashes through more accurate knowledge of driver behavior and other crash factors.

• *Renewal:* Accelerate the renewal of America's highways. The overall goal of this research is to develop a consistent, systematic approach to per-

forming highway renewal that is rapid, causes minimal disruption, and produces long-lived facilities.

• *Reliability:* Provide a highway system with reliable travel times. The overall goal of this research is to provide highway users with reliable travel times by preventing and reducing the impact of nonrecurring incidents.

• *Capacity:* Provide highway capacity in support of the nation's economic, environmental, and social goals. The overall goal of this research is to develop approaches and tools for systematically integrating environmental, economic, and community requirements into the analysis, planning, and design of new highway capacity.

These focus areas were developed through almost 3 years of study and consultation with a broad array of stakeholders to ensure that the most critical needs would be addressed. The overarching approach of the program is to focus on goals that are meaningful to highway users, such as increasing safety, reducing congestion, minimizing disruption to users when roads are being rehabilitated, and providing new capacity that enhances neighborhoods and avoids environmental harm. The products of this research, if widely implemented, have many potential beneficiaries, including those listed in Box S-1.

In recognition of the importance of the implementation of the results of SHRP 2, the legislation authorizing the program included a requirement to submit to Congress a report on implementation of the research results, which became the Statement of Task for the present report. This report, due by February 1, 2009, was to include the following:

• An identification of the most promising results of research conducted under the program (including the most likely beneficiaries of those results);

• A discussion of potential incentives for, impediments to, and methods of implementing the results;

• An estimate of the costs of implementation; and

• Recommendations for how implementation should be conducted, coordinated, and supported in future years, including a discussion of the administrative structure and organization best suited to carrying out those recommendations.

Box S-1

POTENTIAL BENEFICIARIES OF SHRP 2 RESEARCH PRODUCTS

- Taxpayers
- Motorists
- Commercial drivers
- Bus riders
- Shipping and logistics professionals
- Environmental agencies
- Communities, businesses, and owners of event venues served by the highway system
- Railroads
- Utilities
- Automobile manufacturers and suppliers
- Metropolitan planning organizations
- Law enforcement
- Firefighters
- Emergency medical services
- Highway designers, contractors, and suppliers
- State and local transportation agencies

The committee's response to this congressional reporting requirement is summarized below.

FINDINGS

SHRP 2 Research, Promising Results, Potential Users, and Incentives for and Impediments to Implementation

SHRP 2 research was ongoing for less than a year when the committee began the task of preparing this report. No final products of the research are as yet ready for use. The committee studied the plans for and tentative outcomes of the program's early research efforts and consulted with the SHRP 2 governing and technical committees and staff, as well as a variety of stakeholders, to project the ultimate outcomes of the program, its potential users, and the incentives for and impediments to implementation that may be encountered.

Safety

SHRP 2 is taking a systems approach to safety by examining how the driver interacts with the roadway, the vehicle, and environmental factors. Using technologies designed and tested in smaller-scale studies, SHRP 2 will conduct a naturalistic driving study in which the vehicles of 4,000 volunteer drivers will be instrumented with sensors, and data on vehicle and driver performance will be recorded for a year or more. These data will be correlated with roadway data so that all three elements can be studied. This research represents by far the largest study of its kind ever undertaken and promises to serve as a resource for improving highway safety for decades to come. The research conducted in SHRP 2's Safety focus area is expected to produce the following products:

• Initial findings that can be used in the development of new driver, vehicle, and roadway treatments to reduce deaths and injuries and in the modification and improved targeting of existing treatments.

• A rich body of naturalistic driving data, linked with roadway data, of unprecedented size and diversity, as well as tools for the development and evaluation of potential crash countermeasures. Safety researchers and practitioners should be able to use these products to improve highway safety for years, if not decades, into the future.

• Analysis tools [including validated crash surrogates (events or conditions that precede, happen more frequently than, and are highly correlated with crashes)]; research protocols; and specifications for monitoring, recording, and encoding instrumentation that safety researchers can use and build on.

• A site-based video system for studying vehicle behavior on particular roadway segments, such as intersections.

Potential users of these products include safety researchers in the public, private, and academic sectors; highway safety practitioners; and vehicle manufacturers. The data and analysis tools provided by SHRP 2 should help these users design better highways, vehicles, and driver education and enforcement programs. The greatest potential impediment to implementation of these products is the size and complexity of the database. This impediment can be overcome by providing long-term access to the data, as

well as training, expert assistance, and more accessible versions of subsets of the data.

Renewal

The Renewal focus area addresses the need to complete renewal of existing highways quickly, with minimal disruption to the community, and to produce facilities that are long-lasting. These objectives are intended to provide "rapid renewal" consistently and systematically, as opposed to reliance only on isolated special projects. This new way of doing business is built on more collaborative relationships and decision making; better integration of management, planning, design, construction, and maintenance; and more synergistic use of technologies and methods so that optimal benefits can be realized from complementary sets of innovations. Products in the Renewal focus area fall into two general categories:

- Technology: Products in this category include bridge and pavement materials and systems, equipment, designs, and other tools for directly carrying out the renewal work.
- Project delivery: Products in this category support the renewal objectives by addressing construction and asset management, quality control, risk management, and institutional arrangements between transportation agencies and their many partners.

The primary potential users of Renewal products are highway agencies at the state, regional, and local levels. Other users include contractors, materials suppliers, design consultants, utility companies, and railroads. Incentives for product adoption include reduced disruption for roadway users as well as businesses and property owners adjacent to the roadway, less travel delay, streamlined project delivery, greater resource efficiency for highway agencies, and reduced exposure of workers to work zone crashes. A significant impediment to implementation in this area is the relatively high initial construction costs of many innovations that lower life-cycle and user costs. Given restricted budgets and pressure to undertake projects in multiple jurisdictions at once, many agencies may find it difficult to carry out fewer projects with higher initial costs in a given year. They will need information and resources to articulate the benefits of rapid renewal in

terms that are meaningful to the public and to political leaders, training and technical support to guide them through the implementation of innovative approaches, and possibly financial assistance to cover the additional costs associated with demonstrating a new technology.

Reliability

The Reliability focus area is aimed at improving travel time reliability by addressing the portion of the congestion problem that results from nonrecurring events, such as crashes, vehicle breakdowns, inclement weather, special events, and work zones. Products of the research fall into four categories:

- Data, metrics, analysis, and decision support: Research in this category will result in the development of quantitative relationships and analytical tools that can help agencies evaluate the reliability impacts of different strategies and incorporate reliability estimation into planning and operations models. Other products include an archive of travel time data, performance measures, and operational strategies and a guidebook for establishing reliability monitoring programs.
- Institutional change, human behavior, and resource needs: Products of research in this category include guidance for effectively disseminating travel time reliability information to road users, identification of the most effective practices and organizational structures for managing highway systems, and a focused training program for safe and efficient incident response procedures in traffic environments.
- Incorporating reliability into planning, programming, and design: Research in this category will produce improved tools for identifying and evaluating the effectiveness of infrastructure and operational countermeasures and quantifying the impacts of nonrecurring congestion on overall highway capacity. The research will also produce analyses of the impact of highway design features on reliability for incorporation into standard highway design manuals.
- Future needs and opportunities: This research will define user requirements, performance standards, and present and future concepts of operations so as to provide guidance to agencies on the best alternative operations strategies for improving travel time reliability. The research will

also produce a portfolio of innovative ideas, supported by accompanying proofs of concept, aimed at improving reliability.

Implementation of these products will benefit the traveling public; transportation agencies; shipping and logistics concerns; bus operators; providers of police, fire, emergency medical, and towing services; special event managers; and researchers and analysts. The main incentives for product adoption are safer and more efficient highway operations and more efficient use of resources due to more solid foundations for decisions and better analysis, planning, and design tools. Incident responders will experience greater safety and better coordination because of clear, consistent guidelines. Impediments include resistance to institutional change, agency personnel constraints, and a lack of local data to support product use.

Capacity

SHRP 2 Capacity research addresses the challenge of planning and designing new transportation capacity that integrates mobility, economic, environmental, and community needs. Meeting this challenge calls for collaborative decision making in which the right people are involved at the right time with the right information. To be successful, this research must have a framework that is supported by an effective strategy for enhancing the environment, improving economic vitality, and achieving social goals. Products of the Capacity research fall into four categories:

- Elements of collaborative decision making: The central product of the Capacity focus area will be the Collaborative Decision-Making Framework (CDMF), an integrated web-based tool focusing on key decision points in the planning and programming process and supported by tools in the other three categories.
- An ecological approach to surface environmental protection: The products in this category will be an ecosystem-based credits system, a business model, and guidelines that will enable conservation banking or other strategies to go beyond resource-by-resource mitigation.
- Improved tools for analysis of travel behavior: SHRP 2 will provide support for ongoing efforts to develop and use activity-based travel demand models. Research in this category will result in the development of math-

ematical relationships among motorist behavior, pricing, and congestion, and it will demonstrate the effects of highway management strategies on sustainable highway throughput in peak conditions.

• Economic impacts of highway investment: This research will produce before-and-after case studies of economic development impacts, a practitioner's handbook to make development impacts more transparent to non-economists, and improved economic analysis tools.

Potential users of these products are state and local transportation agencies and metropolitan planning organizations. The main incentive for implementing the CDMF and related products is to enable agencies to improve the quality of decisions and deliver projects more quickly. In addition, the CDMF can be expected to improve a transportation agency's relationships with its partners and stakeholders by promoting more transparent communication and decision making. The main potential impediments are the cost of changing agency procedures, insufficient data in some jurisdictions, and the large number of stakeholders that must buy into the framework.

Successful Implementation Strategies

There are many methods for implementing innovations; their success varies across types of products and user groups. The committee identified several methods that appear to be most promising for the implementation of SHRP 2 products:

- Strategic packaging and branding;
- Technical assistance;
- Standards, specifications, guidebooks, and manuals;
- Follow-on research, testing, and evaluation;
- Lead users and demonstration projects;
- Training and education; and
- Long-term stewardship.

Knowledge management and information technology (IT) capabilities are required for all of these strategies. These capabilities include, for example, the ability to establish Internet-based communication and collabora-

tion tools, such as webinars and wikis; the development of communities of practice; and ways to capture learning and knowledge gleaned both in individual focus areas and about implementation itself.

Principal Implementation Agent

While many stakeholders will be involved in SHRP 2 implementation, the effectiveness of a coordinated implementation program will depend in large part on having a strong principal implementation agent, that is, an organization that will lead and support SHRP 2 implementation. The mission of this agent will be to promote and support the effective implementation of SHRP 2 products wherever they can help achieve the goals of the Safety, Renewal, Reliability, and Capacity focus areas.

The principal implementation agent will carry out a number of tasks. One of the first will be to assess the readiness for implementation of each SHRP 2 product and develop implementation plans accordingly. Plans should identify users and others affected by the product and specify the most effective implementation methods for each product. The agent will be responsible for administering competitive processes to provide for the additional research, testing, evaluation, demonstration projects, training, technical support, and other activities necessary to support implementation. Other responsibilities will include arranging for stakeholder involvement, coordinating with related programs, promoting collaboration, tracking the progress of implementation, measuring results, providing knowledge management and IT expertise and tools, and publishing reports and other materials to aid implementation efforts.

Implementation will require strong leadership. A single point person at a high enough level in the organization will be needed to ensure that SHRP 2 implementation receives the necessary visibility and priority. Staff who support the implementation program will require adequate funding, salient technical knowledge, good judgment about people and opportunities, communication and diplomatic skills, foresight, flexibility, dedication, and a willingness to become directly involved in real-world applications. Implementation is a time-intensive task that requires a concentrated focus. Managers must understand this and provide a work environment that allows implementation staff to maintain that focus.

RECOMMENDATIONS

Widespread implementation of SHRP 2 products promises to deliver on the program's overarching goal of providing outstanding customer service for the 21st century. In view of the findings documented in this report, the committee makes the recommendations presented below. These recommendations are rooted in the principles and strategies outlined in Chapter 6 and should be understood in that context.

Recommendation 1: A SHRP 2 implementation program should be established.

Recommendation 2: The Federal Highway Administration should serve as the principal implementation agent for SHRP 2, in partnership with the American Association of State Highway and Transportation Officials, the National Highway Traffic Safety Administration (NHTSA), and the Transportation Research Board. NHTSA should exercise a leadership role in the long-term stewardship of the safety database.

Recommendation 3: Stable and predictable funding should be provided over several years to support SHRP 2 implementation activities. Total funding for the first 6 years of the implementation program is estimated at $400 million. The need for additional funding thereafter should be assessed at the appropriate time. Implementation planning and budgeting should take into account that several SHRP 2 products, especially the safety database, will require long-term support that will extend beyond the initial 6-year period.

Recommendation 4: A formal stakeholder advisory structure should be established to provide strategic guidance on program goals, priorities, and budget allocations, as well as technical advice. At a minimum, this advisory structure should include an executive-level oversight committee for the entire SHRP 2 implementation program and a second oversight committee focused exclusively on administration of the safety database.

Recommendation 5: Detailed implementation plans should be developed as soon as feasible to guide the implementation efforts.

1 Introduction

SHRP 2 overarching theme: Providing outstanding customer service for the 21st century.

SHRP 2 vision: A highway system that actively contributes to improved quality of life for all Americans by providing safe, efficient mobility in an economically, socially, and environmentally responsible manner. (TRB 2001)

The highway system has a pervasive presence in U.S. society. Whether driving, biking, or traveling by bus, many Americans use the nation's roads every day in their personal, professional, family, and social activities. Many of the goods Americans purchase, from clothing and food to furniture and the latest electronic gadgets, have traveled some distance in a truck on the highway system. The system's presence and functioning are generally taken for granted, but doing so is becoming increasingly difficult as highway facilities age and the impacts of exceeded designs and suboptimal operation take their toll.

ISSUES FACING THE NATIONAL HIGHWAY SYSTEM

The 4-million-mile highway system is the backbone of the U.S. economy, carrying 65 percent of the nation's $15 trillion in freight traffic (2006 data from FHWA 2008a), while 88 percent of all person miles traveled in the United States occurred in private vehicles in 2001 (Hu and Reuscher 2004). In addition, the highway network provides passenger and freight links to all other modes of transportation. These facilities have been in constant use

for decades, often exceeding their original design life and traffic volumes. As a result, the system is deteriorating and heavily congested.

The scale of highway renewal needs is suggested by the available national data. Using 1999 obligations, the Transportation Research Board (TRB) (2001) found that resurfacing was being performed on 12.85 percent (20,586 miles) of the National Highway System (NHS) annually, yielding a 7- to 8-year resurfacing cycle for the 160,000-mile system. Reconstruction had been performed on 3,200 miles of roads, implying a 50-year replacement cycle and therefore a need for a 50-year roadway, in contrast to the typical design life of 20 years. Furthermore, the average age of bridges in the national inventory is 40 years; 27.5 percent of this inventory is structurally deficient or functionally obsolete (FHWA 2004).[1]

The available data on the impacts of congestion are staggering. In 2005, congestion cost travelers in 437 urban areas 4.2 billion hours and $78 billion and resulted in the waste of 2.9 billion gallons of fuel (TTI 2007, Exhibit B-11, p. B-19). Congestion is being experienced during more hours of the day and is becoming more volatile, increasing travel time unreliability. The additional fuel consumed and idling vehicles contribute to environmental damage. Congestion may make an individual late for work, miss an appointment, or wait a long time for a bus; indeed, it may determine a person's entire weekday schedule. To the private sector, congestion means higher transportation and logistics costs, fewer deliveries or service calls per day, and wear and tear on employees and vehicle fleets. For truckers who provide just-in-time freight deliveries to manufacturers and other businesses under service-level agreements, the penalties for failing to deliver on time can amount to tens of thousands of dollars.

The magnitude of the infrastructure renewal and congestion problem increases significantly when one considers growth predictions for the next

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[1] These terms are defined as follows by the Federal Highway Administration (FHWA 2004): "Bridges are considered structurally deficient if significant load carrying elements are found to be in poor or worse condition due to deterioration and/or damage, or the adequacy of the waterway opening provided by the bridge is determined to be extremely insufficient to the point of causing intolerable traffic interruptions" (Chapter 15, at www.fhwa.dot.gov/policy/2004cpr/chap15c.htm#body). "Functional adequacy is assessed by comparing the existing geometric configurations to current standards and demands. Disparities between the actual and desired configurations are used to determine whether a bridge should be classified as functionally obsolete" (Chapter 3, at www.fhwa.dot.gov/policy/2004cpr/chap3c.htm#body).

two decades: the U.S. population is predicted to grow by 24 percent by 2030 (Energy Information Administration 2007, Table A2); vehicle miles traveled (VMT) is projected to increase by 60 percent by 2030; truck VMT is projected to increase by 75 percent in the same period (Energy Information Administration 2007, Table 7);[2] and truckloads are predicted to increase by 80 percent, to nearly 23 billion tons, by 2035 (FHWA 2007, Table 2-1). This expected growth calls for better system operation and more rapid renewal of in-place infrastructure to optimize the use of existing capacity and improve travel time reliability. There will be a need for additional highway capacity in selected locations to move motorists and freight, as well as additional capacity in public transit, freight rail, and waterborne transportation. One estimate indicates that an additional 173,000 lane miles of Interstate highway will be needed by 2035 just to maintain the current level of highway performance (PB Consult et al. 2007). This estimate, which assumes high levels of investment in transit and passenger rail during the period, implies adding more than 5,700 lane miles of Interstate highway annually for the next 30 years—nearly comparable with the rate of expansion during the Interstate construction years. About half of the forecast need consists of expansion of existing Interstates, and half consists of upgrades of NHS segments to Interstate standards. Any capacity enhancements will have to be performance driven and outcome based while integrating environmental, economic, and community requirements.

Growth in highway usage has safety implications as well. Some 43,000 deaths and millions of injuries occur on the nation's roads every year, and motor vehicle crashes remain the leading cause of death for those between the ages of 5 and 34 (CDC 2007). Beyond the personal toll, highway crashes are estimated to cost the nation $230 billion annually (Blincoe et al. 2002).[3] Despite significant improvements in recent decades,[4] several

[2] More recent data show VMT falling; for example, VMT in March 2008 was 4.3 percent lower than that in March 2007 (cf. FHWA 2008b). The long-term impact on VMT and VMT projections is not yet clear.

[3] A study sponsored by the American Automobile Association found that fatal and injury crashes cost $162.2 billion in 85 urban areas in 2005, nearly 2.5 times more than the estimated cost of congestion in those areas (Cambridge Systematics and Meyer 2008).

[4] Between 1970 and 2003, the U.S. highway fatality rate—in terms of fatalities per 100 million VMT—declined by 80 percent (Seiffert 2005). If crash rates were the same now as they were in 1966, the annual number of highway fatalities would be 150,000. Improvements are attributable

factors combine to make highway safety a continuing public health challenge. First, the number of fatalities and the fatality rate per million VMT appear to be leveling off after years of decline. Second, an increase in VMT means more exposure to highway crashes. Third, an aging population means more drivers will exhibit age-related cognitive and physical limitations and increased vulnerability to injury. As drivers age, their collision involvement rate and the likelihood of their experiencing a fatal or serious injury in a collision increase. If all else remains constant, the age shift in the U.S. population between now and 2030 can be expected to result in an increase in the number of fatal and serious injury collisions. Finally, in-vehicle technologies and drivers' use of non-vehicle-related communication devices could lead to greater driver workload and provide more sources of distraction. In many respects, the improvements in highway safety seen during the past several decades have been achieved through rather easily implemented strategies, and continuing declines in both fatality rates and numbers of deaths are becoming increasingly difficult to attain. Innovative approaches to safety countermeasures are necessary for continued progress in road safety performance.

Highway and safety professionals implement safety countermeasures across the spectrum of engineering, education, enforcement, and emergency medical services—the "4 E's" of safety. While such efforts are producing continuing improvements in vehicle and roadway design, enforcement, and education, safety professionals are increasingly convinced that substantial future advances in highway safety must be based on a better understanding of the most critical and least understood component of the driving system—the driver. An improved understanding is essential not just for behavior-oriented countermeasures, such as safety belt use and impaired driving enforcement, but also for the development of roadway and vehicle countermeasures that can affect driver performance so that crashes are avoided or reduced in severity.

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to several sources, including vehicle design (air bags, antilock brakes), highway designs and traffic engineering (breakaway signposts, improved intersection designs, better guardrails, better reflectivity of signs and pavement markings), and legislative and enforcement strategies coupled with public education (graduated licensing for young drivers, radar speed enforcement).

ROLE OF RESEARCH AND INNOVATION

Research and innovation have an important role to play in addressing the issues and concerns associated with the building, maintenance, operation, and use of the highway system. In addition to ongoing research programs of the U.S. Department of Transportation, state departments of transportation (DOTs), the National Cooperative Highway Research Program (NCHRP), universities, and private firms, strategic research programs have focused on particular critical needs. The American Association of State Highway Officials[5] Road Test, conducted in the late 1950s, addressed the need for nationwide design standards for the nascent Interstate highway system. In the 1980s, the first Strategic Highway Research Program (SHRP 1[6]) was proposed and conducted to address needs of that time in the areas of asphalt pavements, structural concrete, and winter maintenance. SHRP 1 was a short-term, highly focused research program. Recommended in a study by TRB (1984), SHRP 1 was authorized in 1987 in the Surface Transportation and Uniform Relocation Act. The program received approximately $150 million over 5 years and was administered by a specially created unit of the National Research Council (NRC). The original research plan included six focus areas (later consolidated to four):

- Asphalt,
- Long-term pavement performance,
- Maintenance cost-effectiveness,
- Protection of concrete bridge components,
- Cement and concrete in highway pavements and structures, and
- Chemical control of snow and ice on highways.

In 1991, Congress authorized additional funds to support SHRP 1 implementation. The methods and results of SHRP 1 implementation, as well as principles derived from that experience, are discussed in Chapter 2.

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[5] In 1973, the organization's name was changed to the American Association of State Highway and Transportation Officials as state DOTs increasingly assumed broader transportation responsibilities.

[6] The first Strategic Highway Research Program was known as SHRP; it is referred to as SHRP 1 or the first SHRP in this report to distinguish it from the second Strategic Highway Research Program (SHRP 2).

THE SECOND STRATEGIC HIGHWAY RESEARCH PROGRAM

The success of the first SHRP prompted Congress in 1998 to request a study of whether a new program of a similar short-term, strategic nature was warranted.[7] TRB carried out this study, which was published in 2001 as *Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life* (TRB 2001). The report recommended a $450 million program addressing four strategic focus areas:

- *Safety:* Make a significant improvement in highway safety. The overall goal of this research is to prevent or reduce the severity of highway crashes through more accurate knowledge of driver behavior and other crash factors.
- *Renewal:* Accelerate the renewal of America's highways. The overall goal of this research is to develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities.
- *Reliability:* Provide a highway system with reliable travel times. The overall goal of this research is to provide highway users with reliable travel times by preventing and reducing the impact of nonrecurring incidents.
- *Capacity:* Provide highway capacity in support of the nation's economic, environmental, and social goals. The overall goal of this research is to develop approaches and tools for systematically integrating environmental, economic, and community requirements into the analysis, planning, and design of new highway capacity.

The four focus areas are interrelated, yet each emphasizes a particular set of research objectives, which together advance the overarching theme of SHRP 2: providing outstanding customer service for the 21st century. For example, Reliability and Capacity both address highway capacity, but from two different perspectives: Reliability focuses on increasing the effective capacity available on existing roadways by managing incidents to improve travel time reliability; Capacity focuses on providing new capacity, where appropriate, in a manner that addresses environmental and community issues. Renewal is also connected to Reliability: while Reliability looks at

[7] Transportation Equity Act for the 21st Century, Public Law 105-178, Section 5112, "Study of a Future Strategic Highway Research Program."

management, planning, and analytical approaches that can be used by a transportation agency to reduce the impacts on travel time reliability due to a wide variety of potentially disruptive events, Renewal focuses on one kind of event—work zones—and specifically addresses how the construction aspect of the work can be planned and executed to reduce disruption. Improvements in highway safety resulting from SHRP 2 Safety research will also reduce disruption from highway crashes.

These focus areas were developed through almost 3 years of study and consultation with a broad array of stakeholders to ensure that the most critical needs would be addressed. As reflected in the overarching theme of providing outstanding customer service for the 21st century, the committee that authored *Special Report 260* focused on goals that were meaningful to highway users, such as increasing safety, reducing congestion, minimizing disruption to users when roads are being rehabilitated, and providing new capacity that enhances neighborhoods and avoids environmental harm. This approach contrasts somewhat with that of the first SHRP, which emphasized the reduced costs and increased efficiency that highway agencies would realize from implementing the program's results. Another salient characteristic of SHRP 2 is that it is focused more on changing the way highway agencies do business than on producing a number of technology products. Changing institutions and processes is risky, especially in the public sector. SHRP 2 will produce methods and guidance, as well as technologies, designed to help agencies make the changes necessary to better serve their customers while managing the risk involved with institutional change. The products of SHRP 2 research, if widely implemented, have many potential beneficiaries, including those listed in Box 1-1.

Interim Planning

The American Association of State Highway and Transportation Officials (AASHTO) endorsed the recommendations of *Special Report 260* and proposed to Congress that the program be funded at the recommended level with funds authorized for the federal-aid highway program. In the meantime, the state DOTs, through NCHRP, and the Federal Highway Administration (FHWA) funded the development of detailed research plans for each of the four focus areas. These plans were made available on TRB's website, and a summary was published as *NCHRP Report 510: Interim Planning for a*

Box 1-1

POTENTIAL BENEFICIARIES OF SHRP 2 RESEARCH PRODUCTS

- Taxpayers
- Motorists
- Commercial drivers
- Bus riders
- Shipping and logistics professionals
- Environmental agencies
- Communities, businesses, and owners of event venues served by the highway system
- Railroads
- Utilities
- Automobile manufacturers and suppliers
- Metropolitan planning organizations
- Law enforcement
- Firefighters
- Emergency medical services
- Highway designers, contractors, and suppliers
- State and local transportation agencies

Future Strategic Highway Research Program: Summary Report (TRB 2003).[8] The report envisioned a program funded at $75 million annually over a 6-year period, starting in federal fiscal year (FY) 2004 (October 2003). It also cited a recommendation from AASHTO that the program be administered by TRB under a three-tiered stakeholder governance structure.

Authorization

On August 10, 2005, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law. Section 5210 of the act authorized a "future strategic highway research program" at a nominal level of $51.25 million annually over 4 years (FY 2006–2009), for a total of $205 million. The four research focus areas recommended in *Special Report 260* and developed in *NCHRP Report 510* were

[8] The original research plans are still available at www.trb.org/shrp2/SHRPII_Background.asp.

specified as the content of the research program.[9] The actual appropriations for SHRP 2 are anticipated to total approximately $170 million over 4 years,[10] or less than 40 percent of the amount estimated as necessary to carry out the plans proposed in *NCHRP Report 510*.

Establishment

In January 2006, a memorandum of understanding (MOU) was signed by FHWA, AASHTO, and NRC. The MOU established a partnership among the three organizations to carry out SHRP 2 and described the basic governance structure. In March 2006, SHRP 2 was officially inaugurated when funding was made available through a cooperative agreement between FHWA and NRC.

The governance structure laid out in the MOU is essentially the three-tiered approach outlined in *NCHRP Report 510:*

- An Oversight Committee is responsible for the overall program. This responsibility includes approving annual work plans, budgets, and contractor awards.
- A Technical Coordinating Committee (TCC) guides the research under each focus area by developing the annual work plans and monitoring the progress of all contracts in the TCC's focus area.
- Expert Task Groups (ETGs) assist in two ways: some develop requests for proposals (RFPs), review proposals, and make recommendations for award to the Oversight Committee; others ("technical" ETGs) provide expert assistance to the TCCs in carrying out their program and project monitoring responsibilities.

Each of these groups has members or liaisons, or both, from federal, state, and local government; universities; and the private sector. Most also have international representation to facilitate coordination with research conducted in other countries. The purpose of such an extensive stakeholder governance structure is to ensure that the research remains focused on critical needs; that the best expertise is brought to bear in guiding the program;

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[9] The focus areas are described in detail in Chapters 2 through 5.

[10] The total funding and time frame remained uncertain at the time of this writing.

and that potential users are involved from the beginning, thereby increasing the success of the eventual implementation of research results. As of this writing, nearly 400 individuals have been involved in approximately 40 groups (mainly ETGs).

As a result of the 60 percent reduction in the program's funding and the nearly one-third reduction in its duration,[11] the first task of the governance committees was to rescope the program significantly to reflect the new financial and time constraints. The TCCs, in consultation with FHWA staff and with the contractors and volunteers involved in the development of the original research plan, rescoped the plans for the four focus areas using the following process and criteria:

1. The first step was to review current plans to identify
   - Relevant research completed or initiated since the original plan was developed,
   - Projects to be deferred until the implementation phase,
   - Projects out of scale with the budget or the time frame,
   - Overlapping projects (within SHRP 2), and
   - Projects duplicative of other initiatives (outside of SHRP 2).
2. This step was followed by an initial revision of plans and budgets, which involved several efforts:
   - A first draft revision by the contractors that had prepared the original plans,
   - Detailed literature searches by staff to identify related or possibly duplicative research,
   - Consultation with FHWA to identify related or possibly duplicative research, and
   - Solicitation of feedback from selected experts and stakeholders.
3. On the basis of the additional information thus gathered, the original contractors prepared new, detailed rescoping options, with justification for the changes.
4. These detailed drafts were distributed to the TCCs for review.
5. At their initial meetings in early 2006, the TCCs adopted revised research plans.

[11] The original program duration assumed 6 years of authorized funding to be spent over 9 years; the actual time frame is determined by 4 years of authorization spent over nearly 7 years.

Subsequent modifications have been made, largely in response to outcomes of early tasks in the first set of research projects. While essentially "final" research plans have been adopted by all the TCCs and approved by the SHRP 2 Oversight Committee, an ongoing task of the TCCs is to adjust their plans as necessary in response to research results, funding changes, and other developments to ensure that SHRP 2 research remains relevant and focused on its strategic goals. Ongoing coordination with other research programs of FHWA, the National Highway Traffic Safety Administration (NHTSA), NCHRP, state DOTs, universities, and other countries will help avoid unnecessary duplication and leverage the efforts of these other programs.

Administration

The administration of the program was designed to ensure that SHRP 2 would remain focused on the customer-oriented vision and research goals set forth in *Special Report 260*. Stakeholder guidance is a principal feature of SHRP 2 administration: the ultimate users of the program's research products are engaged in defining and prioritizing the research and overseeing its conduct toward useful results. Each fall the SHRP 2 TCCs prepare the next year's work program, which is reviewed and approved by the Oversight Committee and provided to FHWA for concurrence. The annual work plans establish a schedule for two rounds of projects. Typically, RFPs are advertised in March and July, with proposals due 6 weeks after advertisement and awards made by the Oversight Committee in June and November. Ongoing oversight of projects in each focus area is carried out by the respective TCC with assistance of the technical ETGs as needed. Semiannual progress reports are provided to the Oversight Committee, FHWA, and TRB's Executive Committee. A public annual report is also produced.

Regular communication about the program is carried out through a number of mechanisms in addition to formal progress reports. Each state DOT and several countries have appointed SHRP 2 coordinators or liaisons who receive periodic updates, as do the AASHTO Board of Directors and several AASHTO committees. Quarterly reports are posted on the SHRP 2 website, where interested parties can also learn about new RFPs; check project status; and be informed about SHRP 2 activities, such as workshops and symposia, in which they can participate. Technical briefs describing each focus

area are updated every few months, printed for distribution at technical meetings, and posted on the website. SHRP 2 news is also included in TRB's e-newsletter, which is sent weekly to 32,000 recipients. As research results are produced, appropriate dissemination mechanisms are considered, including printed or web publication, CD, DVD, or other media. A special series called *First Fruits* publishes early products and results from projects not yet completed so that outcomes can be made available to potential users as soon as possible.

Implementation

The original plan for SHRP 2 integrated some implementation-related activities into the originally proposed $450 million research program. These activities included identification of potential users, dissemination of research findings, testing and evaluation, demonstration projects, conferences, workshops, information clearinghouses, and early training efforts. The reductions in the program's funding and duration forced the elimination of some of these implementation activities, especially those that were more expensive and time-consuming and would naturally come toward the end of the research and development process, such as testing and demonstration projects.

The inclusion in SAFETEA-LU of a requirement to submit the present report on SHRP 2 implementation suggests that Congress is aware of the need to provide additional time and money to support the implementation of SHRP 2 results, if they so merit. This was the committee's operating assumption and drove the committees' approach to fulfilling its charge.

STUDY APPROACH

The first step in the approach to this study was to ascertain what promising results, if any, SHRP 2 could be expected to produce. Doing so posed a challenge for the committee because the first SHRP 2 research contracts were signed less than a year before the committee began its work. Although a number of interim reports and provisional results have been produced to date, no final product is ready for use. Nevertheless, the report's due date necessitated an early start, so the committee used several mechanisms to identify prospective SHRP 2 products and ascertain their potential useful-

ness. At the committee's first meeting, a representative of each TCC and corresponding SHRP 2 staff presented an overview of their respective focus area and its expected outcomes. The committee questioned them about potential users, possible incentives and impediments (including persons or institutions that might resist implementation), and effective implementation methods. The committee also invited representatives from key stakeholder groups—state DOTs, county transportation agencies, metropolitan planning organizations, construction and materials suppliers, engineering design firms, universities, and technology transfer agents—to comment on the potential usefulness of anticipated SHRP 2 products and methods of implementation and technology transfer preferred by their constituencies. In addition, the committee requested that each TCC dedicate a portion of its spring 2008 meeting to discussing the issues to be addressed in this report—promising results; potential users; implementation incentives, impediments, costs, and mechanisms—and to provide the committee with results of their deliberations.

Addressing institutional issues is a major aspect of successful implementation and a specific component of the congressional request for this report. Therefore, the committee worked with FHWA, NHTSA, and AASHTO[12] to study potential options for structuring SHRP 2 implementation. As described in Chapter 2, AASHTO and FHWA played major roles in the implementation of the first SHRP, so the committee asked these two organizations to assess that experience, to consider the similarities and differences between SHRP 1 and SHRP 2, and to propose how each organization might contribute to SHRP 2 implementation. A significant outcome of SHRP 2 will be safety-related data of unprecedented scale and scope. NHTSA's experience in administering safety data that are used by researchers and practitioners nationwide makes that agency uniquely suited to assist the committee in this area. FHWA conducted an agencywide workshop, with participation from AASHTO and NHTSA, and developed principles and a proposed institutional structure to support SHRP 2 implementation. The results of this effort were presented and discussed at the committee's June 2008 meeting.

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[12] Section 5210 of SAFETEA-LU specifically requires TRB to consult with these three organizations, each of which appointed a liaison to the committee.

ORGANIZATION OF THE REPORT

In Chapters 2 through 5, each research focus area within SHRP 2—Safety, Renewal, Reliability, and Capacity—is examined with respect to the following issues: promising research results; potential users, incentives, and impediments; implementation requirements; and appropriate implementation methods and activities. Chapter 6 outlines a set of implementation principles and key strategies for SHRP 2 based on experience with implementation of the first SHRP. Chapter 7 applies the implementation principles and key strategies set forth in Chapter 6 to formulate a programwide approach to SHRP 2 implementation. Finally, the committee's recommendations for implementation activities, institutional mechanisms, and funding are presented in Chapter 8.

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Abbreviations

CDC	Centers for Disease Control and Prevention
FHWA	Federal Highway Administration
TRB	Transportation Research Board
TTI	Texas Transportation Institute

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Safety Focus Area

SHRP 2 Safety program goal: To prevent or reduce the severity of highway crashes through more accurate knowledge of driver behavior and other crash factors.

Driver behavior has been identified as the major factor in approximately 90 percent of roadway crashes (Sabey and Staughton 1975; Treat et al. 1979; Hendricks et al. 2001). Yet the driver remains the most difficult part of the system to study. Driving simulators and studies performed on test tracks or in special test vehicles have made important contributions to understanding the driver, but these methods do not always provide good representations of real-world driving conditions or behavior. Surveying drivers about their behavior and interviewing them after a crash fail to yield very accurate or reliable reports of real behavior, not only because people are biased in their assessments of their own driving prowess or fear liability in the case of a crash but also because so much driver behavior occurs without full conscious awareness. In the case of crashes, events occur so quickly and many responses are so automatic that drivers often cannot remember how they acted—whether they braked or accelerated, for example.

Advances in sensors, cameras, computing, and communications technologies have now made it possible to gather real-world driving data that have never before been accessible to highway safety professionals. Sophisticated instrumentation packages can be installed inconspicuously in volunteers' vehicles to collect data on speed, acceleration, and braking; use of signals, lights, wipers, and safety belts; lane position; and more. Extremely small cameras can capture looking and motor behavior without the driver's

noticing the cameras or being reminded of their presence. This information can be collected not just when a crash or unusual incident occurs, but throughout the course of ordinary driving.

For the first time, then, objective, scientific information can be obtained about what happens when people crash, when they experience a near-crash, or when they drive without incident. This information will make it possible to draw confident conclusions about the crash risks posed by various factors and whether those factors are related to the vehicle, the driver, the roadway and traffic environment, or some interaction of these. This kind of safety research is sometimes referred to as a "naturalistic driving study" because it captures driving in natural or real-world circumstances. The benefits of this new knowledge will be realized in more effective use of existing safety countermeasures and in the development of entirely new safety strategies.

An example of these benefits is the use of actual driving data as educational feedback for younger drivers (see Box 2-1). The results of naturalistic driving studies are also valuable to states as they develop Strategic Highway Safety Plans. These plans call for data-driven, highly effective strategies that maximize safety benefits, in terms of reductions in deaths and serious injuries, for each dollar invested. In these initiatives, states are considering

Box 2-1

IOWA TEEN DRIVER STUDY

Teen drivers exhibit high crash rates, especially early in their driving experience. The University of Iowa demonstrated the use of in-vehicle sensors and cameras as an educational tool to help parents coach their children in better driving skills. The instrumentation on the teenagers' vehicles was configured to save data when certain thresholds of acceleration were triggered (in contrast to the SHRP 2 study, in which data will be collected and saved continuously). Each week the events captured by the instrumentation were shared with the drivers and their parents as an educational opportunity. The teens with the highest frequency of safety-relevant events improved their driving by 72 percent in the first 9 weeks of the intervention (McGehee et al. 2007). Insurance companies have begun to offer vehicle instrumentation as a service to parents insuring their teenage drivers.

behavioral programs as well as roadway initiatives, bringing together "4E" (engineering, education, enforcement, and emergency medical services) organizations to determine what programs are needed across the board. To make these prioritization processes work well, states need not only more knowledge about the effectiveness of current behavioral programs but also knowledge concerning what new behavioral treatments are needed to further reduce the current crash toll. Similarly, vehicle manufacturers and their suppliers, the National Highway Traffic Safety Administration (NHTSA), and others can use the knowledge provided by naturalistic studies to target their safety efforts.

SHRP 2 SAFETY RESEARCH

SHRP 2 is taking a systems approach to safety by examining how the driver interacts with the roadway, the vehicle, and environmental factors. Using technologies designed and tested in smaller-scale studies, SHRP 2 will instrument the vehicles of 4,000 volunteer drivers and record their driving for a year or more. The drivers will be men and women in various age groups, driving different types of light vehicles, from different socioeconomic strata, and from different geographic areas across the United States. In addition to having instrumentation in their vehicles, the drivers will take a battery of tests and respond to questionnaires concerning a number of factors that may be related to driving performance so these factors can be studied in relation to actual driving behavior. The study will collect data not only on the drivers' behavior but also on their vehicles' characteristics and performance. To capture the roadway element of the safety interaction, data on road type, geometry, shoulders, safety furniture, signage, pavement markings, and more will be collected for the roads used by the volunteer drivers during the study. Through the Global Positioning System (GPS), driver behavior at various locations will be correlated with roadway and roadside features at those locations. In addition, data on environmental variables such as traffic, lighting, and weather conditions will be collected to the extent feasible, whether from the in-vehicle data systems or by other means.

The research described above—known as the SHRP 2 naturalistic driving study—represents by far the largest study of its type ever undertaken and promises to be a resource for improving highway safety for decades to

come. The specific research projects included under the SHRP 2 Safety program are listed in Appendix B.

In the original plan for SHRP 2 safety research (TRB 2003), the naturalistic, or in-vehicle, driving study was to form one track of research, while a second track would employ a "site-based" research strategy. The site-based approach involves instrumenting roadway segments or intersections with multiple overhead cameras and automating vehicle trajectory tracking to study the driving behavior of multiple vehicles at specific locations. These two tracks of research are complementary in nature. The naturalistic driving approach provides detailed information about a single driver and vehicle over an extended period of time but little information about surrounding vehicles and the behavior of their drivers. The site-based approach, on the other hand, provides little information about individual drivers (it would not reveal, for example, whether a driver was wearing a safety belt or using a cell phone) but useful information about the movements of all the vehicles passing through a targeted segment of the roadway. Thus the site-based technique makes it possible to study the interactions among drivers in a complex driving scenario. Specific sites, rather than the roads chosen by the drivers, can be studied, and site characteristics can be varied to examine changes in such features as signal timing, speed limits, signage, and pavement markings.

When it became clear that SHRP 2 funding would be significantly less than originally proposed, the SHRP 2 Safety Technical Coordinating Committee chose to focus on the in-vehicle track of research more than on the site-based track for the following reasons:

- The technical feasibility of the in-vehicle instrumentation had already been demonstrated in smaller-scale studies, while the site-based technology required some additional development before it could be used in large-scale field work.
- The opportunity to conduct the naturalistic driving study under SHRP 2 is truly unique because the scope and scale of this study make it highly unlikely that it will be undertaken by anyone else, while the final development and use of the site-based technology could be accomplished more easily by others in smaller-scale studies if it proves technically feasible.
- The in-vehicle strategy promises to provide unprecedented insights into driving that could lead to significant improvements in highway safety at the

national level in the long run and that cannot be provided through any other research approach available today.

At the same time, the site-based approach was considered promising enough to merit some investment by SHRP 2. The program has funded a project to further develop the site-based technology in hopes of creating a robust tool that can be easily deployed to study different types of highway locations. Of particular interest are intersections, where 45 percent of reported crashes and 21 percent of fatalities occur (FHWA 2008). Intersections are locations of multiple and complex interactions of many drivers, making them appropriate targets for the site-based approach. If the SHRP 2 project in this area is successful, university researchers and state and local safety engineers could use the site-based approach to study issues associated with particular roadway geometries that appear to be crash prone. If SHRP 2 were to receive additional funding, follow-on projects for field deployment and analysis could be conducted within the program.

PROMISING PRODUCTS, AND POTENTIAL USERS, INCENTIVES, AND BARRIERS

SHRP 2's Safety focus area is expected to produce the following products:

- Initial findings that can be used in developing new driver, vehicle, and roadway treatments to reduce deaths and injuries and in improving existing treatments.
- A rich source of naturalistic driving data, linked with roadway data, of unprecedented size and diversity, as well as tools for the development and evaluation of potential crash countermeasures. Safety researchers and practitioners will be able to use these data and tools to improve highway safety for years, if not decades, into the future.
- Analysis tools [including validated crash surrogates (defined later in the chapter)]; research protocols; and specifications for monitoring, recording, and encoding instrumentation that safety researchers will be able to use and build on.
- A site-based video system for studying vehicle behavior on particular roadway segments, such as intersections.

Initial Findings

The current SHRP 2 effort will provide answers to a limited number of high-priority safety questions. Safety practitioners and researchers nationwide were consulted to develop a list of nearly 400 safety questions that can be addressed with the use of SHRP 2 data. Box 2-2 contains examples of the types of questions being considered. As of this writing, the questions were still being prioritized to determine which ones will actually be addressed within SHRP 2. The answers to these questions will provide safety professionals with guidance for more effective safety strategies and are likely to

Box 2-2

SELECTED RESEARCH QUESTIONS GENERATED FOR SHRP 2

Lane-Keeping and Run-off-the-Road Crashes

- Does lane-keeping vary with driver age, gender, or vehicle type?
- Does risk of lane departure vary by road type, traffic volume, superelevation, or presence of opposing traffic?
- How are run-off-the-road crashes affected by different roadway geometries, shoulder widths, speed limits, signage, or pavement markings?
- What is the role of following distance in lane-change/merge crashes?
- How does aggressive driving behavior affect the risk of crashes or near-crashes?
- Is there a relationship between aggressive driving behaviors and run-off-the-road crashes or near-crashes?

Intersection Safety

- How do roadway design, traffic control variables, and signage influence behavior at intersections, such as braking, gap acceptance, and decision to turn at intersections?
- How does roadway design influence compliance with traffic controls at intersections?
- What is the effect of access points near the intersection?

In-Vehicle Technologies

- Is the frequency of use of infotainment or navigation devices affected by road type or traffic volume?
- What is the influence of road geometry on driver behavior during technology-related tasks?

yield input to future editions of the *Highway Safety Manual* and the *Comprehensive Human Factors Guidelines for Road Systems* (TRB 2005). The studies conducted for the chosen questions will also serve as a demonstration of the uses and usefulness of SHRP 2 data.

Box 2-3 provides examples of findings from other naturalistic driving studies performed at the Virginia Tech Transportation Institute, while Box 2-4 describes an array of uses of similar data from field operational tests performed at the University of Michigan Transportation Research Institute. These studies are much smaller than the SHRP 2 naturalistic driving study and do not involve as wide a variety of drivers and geographic locations or the more detailed roadway data that SHRP 2 will have. Nonetheless, their findings are illustrative of what can be learned from such studies. In addition to developing new findings, the larger SHRP 2 study will produce databases that can be used to verify the findings of smaller studies and test the robustness of these findings under different scenarios.

In-Vehicle Data

The 2-year SHRP 2 naturalistic driving study will produce a number of databases for use by researchers and practitioners from universities, highway agencies, automobile manufacturers, and others concerned with highway safety. The raw data—from cameras, vehicle instrumentation, and roadway data collection—will be preserved for researchers who have interest and skills in mining these data. Reduced data sets—more accessible and more user-friendly versions of the raw data or some subsets thereof—will be useful to both researchers and practitioners. In many cases, safety practitioners will be indirect users of the data in that they will engage researchers to be the direct users.

Three main components will collect data on or from the volunteers' vehicles. The first will collect data on speed, acceleration, braking, seat belt use, and other vehicle-related factors. The second will be a set of inconspicuous cameras that will capture the volunteer's face and the driver's view out the front, rear, and side of the vehicle. The third will be a radar unit to capture the presence of other vehicles or objects near the subject vehicle. The data from these components will be encrypted, be transmitted to a secure location, undergo quality checks, and be stored for reduction and analysis. In addition to these data, as noted above, the volunteer drivers will be asked

Box 2-3

EXAMPLES OF FINDINGS FROM NATURALISTIC DRIVING STUDIES

The Virginia Tech Transportation Institute (VTTI) has conducted a number of small naturalistic driving studies, most notably a study in which 100 volunteers drove instrumented vehicles for 1 year. VTTI has also conducted studies focused on teenage drivers and on truck drivers. The findings described here illustrate the types of information that can be gleaned from naturalistic driving studies and the kinds of countermeasures that may be developed as a result.

Driver inattention—particularly looking away from the roadway just before an unexpected event or condition—is the largest contributing factor to unsafe events such as crashes and near-crashes. Secondary tasks (those unrelated to driving) and external distractions account for most inattention-related risk. The highest risk is associated with looking away many times or for long periods of time. The kinds of secondary tasks associated with such frequent or prolonged inattention include dialing a cell phone, text messaging, manipulating an MP3 player, and using the Internet. Teenage drivers are four times more likely than adult drivers to be involved in a crash or near-crash while performing a secondary task. Such findings contributed to a Virginia law banning the use of handheld electronic devices by teen drivers. High-tech countermeasures, such as driver "eyes-forward" monitors, in combination with other crash avoidance technology, could be used to warn drivers of unsafe behaviors and changing circumstances.

Driver drowsiness is a contributing factor in 15 to 20 percent of crashes and other safety-related incidents involving long-haul trucking, local and short-haul trucking, and light-vehicle driving, and it can occur at any time of day. Crash and near-crash risk is 6 to 8 times higher when driving while drowsy than when driving while alert. A study of truck drivers found that long-haul "team" truck drivers have poorer sleep quality but sleep for longer periods and are generally safer than "single" drivers. Among local and short-haul truckers, drowsiness was found to be most closely associated with beginning the workweek in a tired state. Potential countermeasures include adjustments to hours-of-service regulations, electronic log books for truckers, and high-tech driver alertness monitors for all types of drivers.

Evaluation of countermeasures can be carried out by using naturalistic driving data. For example, in-vehicle forward collision warning algorithms were compared by overlaying data from VTTI's 100-car study on actual crash and near-crash data. The use of real-world scenarios makes it possible to test whether the driver could have avoided a crash and under what circumstances the system would fail to activate for a real crash. These results can be used to refine existing countermeasures and to estimate the crash avoidance benefits of countermeasures under development.

SOURCE: VTTI (cf. Hanowski et al. 2000; Dingus et al. 2001; Dingus et al. 2005; Dingus et al. in progress; Blanco et al. in progress).

Box 2-4

ADDITIONAL EXAMPLES OF THE USEFULNESS OF IN-VEHICLE DATA

The University of Michigan Transportation Research Institute has collected naturalistic driving data in a number of field operational tests. More than 800,000 miles of driving data have been obtained from both light passenger vehicles and heavy trucks, including hundreds of data channels from the vehicle; from video; and from add-on instrumentation such as radar, lidar, and inertial motion sensors. These data were originally collected to evaluate the performance and use of new types of safety systems on the vehicles, but the majority of the data are applicable to research and analysis across a wide spectrum of topics involving vehicles and highways. For example, General Motors used these data to develop an algorithm for a forward collision warning system and to assess the safety impact of adaptive cruise control. The University of Michigan has used the data to study highway safety and vehicle use patterns relative to the urban environment, to model driving behavior, and to analyze fuel efficiency to support the design of future hybrid vehicles. A project funded by the Alzheimer's Association used the data as a benchmark for evaluating performance and likely safety concerns for drivers suffering from early-stage dementia. In most cases, the information obtained from these data cannot be obtained from any other source.

Source: University of Michigan Transportation Research Institute.

to take a number of tests and respond to questionnaires to provide information about themselves—such as their visual acuity, psychomotor skill, physical capability, risk taking and risk perception, sleep hygiene, medical conditions and medications, and driving knowledge and history—that can be anonymously correlated with the driving data.

Another data component of the naturalistic driving study—a component never before included at this level of detail in such a study—is extensive roadway data on curves and grades, intersection locations and characteristics, pavement and shoulder types, presence and types of signs, pavement markings, guardrails, and the like. Although states routinely collect roadway data for infrastructure assessment, inventory, and asset management purposes, these data are limited. They do not always cover all roads in a jurisdiction, they may not cover locally owned roads, and they may not include all the elements needed for safety analyses. Having these data will allow SHRP 2

researchers to develop greatly improved knowledge about the relationship of these features to safety outcomes. This knowledge can be used to develop better tools for the design and selection of safety countermeasures.

SHRP 2 will collect data of unprecedented quantity and detail on motor vehicle use, near-collisions, and collisions. These data will enable public health researchers and motor vehicle safety practitioners to probe and understand the conjunction of events and conditional circumstances that lead to collisions and near-collisions in a way never before possible. The data will make it possible to identify and prioritize roadway traffic safety challenges, develop and assess potential countermeasures, and deploy those countermeasures that provide a net societal benefit. It is not unreasonable to believe that the countermeasures identified, developed, and deployed as a result of the SHRP 2 study could reduce motor vehicle–related fatalities and serious injuries by tens of thousands annually. The incident-free data collected—which safety professionals refer to as "exposure"—will provide the basis for comparisons of crash risk under different circumstances and involving different factors. Objective data on what really occurs before and during a crash or near-crash—how fast the driver was really going; when he or she braked; and how speed and braking are affected by cell phone use, fatigue, or other factors—will provide better understanding than biased and incomplete postcrash recollections of drivers and observers that until now have served as the primary source of such data.

SHRP 2 data will also make it possible to study how drivers react to different roadway and environmental features and how their reactions affect crash risk. A strength of the SHRP 2 data, never available previously, will be the synthesis of highly detailed roadway, environmental, and driver data. The SHRP 2 data will enable study of how such factors as driving speed, braking, steering, and attention change with changes in roadway and environmental features—such as lane width, signing, pavement type, pavement markings, shoulder type and width, lighting conditions, and prevailing weather conditions. This in turn should allow some roadway countermeasures to be explored analytically, with a wide variety of drivers, by taking advantage of features already in place in various areas instead of implementing the features in an experimental situation and waiting a long time to acquire crash data. For example, SHRP 2 will help in understanding when and where speeding is most likely to occur; when it poses the greatest crash risk; and which

countermeasures, such as innovative signing and roadway treatments, are most effective in reducing unsafe speeds. Such insights, paired with technology (such as digital maps), will provide the opportunity to deliver notice to drivers of changing roadway and environmental conditions and thereby allow advanced driver response.

Driver distraction is another important area in which SHRP 2 research can contribute by identifying the sources of distraction and calculating the crash risk associated with different sources. Cell phones, in-vehicle devices, and other technologies are hypothesized to be a major source of distraction—hypotheses that can be tested by SHRP 2. Cell phones in particular are a rapidly growing concern. Approximately 230 million cell phones are now in use in the United States. Current NHTSA surveys show that about 6 percent of drivers are using cell phones at any given moment (NHTSA 2008). The SHRP 2 data will make it possible to examine differences in crash risk while drivers are using a cell phone under various driving conditions (e.g., road type, traffic volume, speed) or by demographic identifiers (age or driving experience, for example). Results of research on these questions could lead to a number of safety countermeasures. Rumble strips or other roadway design features could help bring a driver's attention back to the driving task. In-vehicle technology could be developed to prevent cell phones from functioning while drivers are operating in challenging traffic and environmental conditions with high cognitive demand and to enable safe cell phone use in low-demand conditions. Laws on the use of cell phones (for example, hands-free versus handheld and restrictions on younger drivers) could be based on empirical evidence of risk. Education programs and new technologies could perhaps be tailored to particular audiences and driving behaviors.

Other nomadic devices that can be brought into the vehicle—including television, laptops, MP3 players, texting devices, and GPS devices—are a rapidly growing issue, though far less well documented than cell phones. There is some evidence that they pose a greater problem for young drivers who are the early adopters of these devices, use them frequently, and may think they can multitask without being distracted to a level that compromises the cognitive capacity they devote to the driving task. SHRP 2 data will allow the risks associated with these devices to be studied and quantified so that appropriate countermeasures, possibly similar to those suggested for cell phones, can be effectively applied.

New technologies increasingly being added to the vehicle also raise questions about distraction. Do onboard navigation devices contribute to distraction? Do in-vehicle warning systems (lane departure, collision, speed, and traction warning systems, for instance) contribute to distraction, or are they a potential solution to all driver distraction issues? SHRP 2 data will allow algorithms for these systems to be developed and tested. For example, developers of lane departure or collision warning systems will want to minimize the number of false positives (i.e., the warning sounds when it is not needed, annoys the driver, and possibly leads to ignoring the warning when it is real) and false negatives (i.e., the warning does not sound until it is too late for the driver to react). The task for technology and system designers is to integrate new systems that provide value and function without adding distracting operational features and to restrict access to operational features during periods of high driver workload and cognitive demand. SHRP 2 data will be able to be matched to the typology of crashes developed by the Volpe National Transportation Systems Center (Najm and Smith 2007) and enable an understanding of collision morphology (causal factors accumulating to cause a crash or near-crash). As they develop a profound understanding of how collisions occur and under what contributing conditions, safety professionals will be able to better conceive, develop, and assess potential countermeasures.

The major barrier or challenge to the implementation of SHRP 2 Safety results is the need to house and maintain the data—updating hardware and software as appropriate; providing security; and staffing a center that provides access to the data, assistance, and other services to researchers and practitioners. Significant costs are involved, and funding must be stable over time to avoid the loss of data availability, to provide training and support, and to avoid hardware or software obsolescence. In addition, funding is needed to help ensure exposure of the data to both safety researchers and researchers in other fields who might have unique ideas about how to use them to derive new knowledge and to help in providing web- and university-based training courses.

Research and Analysis Tools

In carrying out the naturalistic driving study, SHRP 2 will develop or improve on a number of tools that can be used by both safety researchers and

planners. Researchers may adopt the research protocols and management approaches developed for the study as guidelines, or perhaps even de facto standards, for the conduct of similar studies in the future. Because the SHRP 2 study will involve thousands of volunteers throughout the country and make use of multiple contractors, it will advance the highway safety research community's knowledge concerning studies with human subjects and how to work with multiple institutional review boards (IRBs) for such research.[1]

All of these tools and the knowledge gained will contribute to a new way of approaching highway safety based on more scientific understanding of risk factors and driver behavior. They also may lead to revised data needs with respect to crash reporting, roadway inventory, driver characteristics, and other safety-related factors as part of a comprehensive approach to asset management. The safety community currently experiences great difficulty in achieving and maintaining adequate attention to and investment in high-quality safety data collection programs. SHRP 2 results should help define the most relevant sets of data that should be gathered by state and local entities so that data collection programs can be cost-effective and fully justified to leadership.

Another analysis tool expected from SHRP 2 is crash surrogates—events or conditions that precede crashes, happen more frequently than crashes, and are highly correlated with crashes. For example, unintentional lane departures may be a surrogate for run-off-the-road crashes. The establishment of surrogates for major crash types could revolutionize the evaluation of safety countermeasures. Currently, to evaluate the effectiveness of a countermeasure in preventing crashes, a safety professional must spend years collecting crash data before and after the countermeasure has been applied. Using surrogates would take less time because surrogates take place more frequently than crashes; their use would therefore reduce, if not eliminate, the need to wait for actual crashes to occur to ascertain the effectiveness of countermeasures.

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[1] An IRB is an ethics board that reviews and approves research involving human subjects to ensure that the subjects' rights and safety are protected. Universities and other research institutions that perform medical and social science research typically have one or more IRBs. The SHRP 2 naturalistic driving study will involve as many as a dozen IRBs because of the number of contractors engaged in the research.

Site-Based Video System

If SHRP 2 can demonstrate the technical feasibility of the site-based safety research tool—the system of overhead cameras and automated vehicle trajectory tracking—this tool could be used by highway safety professionals to study driving behavior at locations of particular interest. The system, which is intended to be deployable at different types of locations, could be used by state and local agencies to evaluate new intersection geometries, different traffic signal timing, various warning signs, pavement markings at hazardous curves or at entrances to work zones, or other countermeasures. This could be accomplished by setting up the system before and after such a change has been made and studying its effect on speed, lane changing, gap acceptance, or other behaviors of interest. As in the naturalistic driving study, the site-based tool could be used to discover crash surrogates, which could be analyzed in lieu of actual crashes to determine the safety impacts of a countermeasure. At its current funding level, SHRP 2 will not be conducting these analyses itself. If the system can be demonstrated to work, however, such studies would be within the capacity of many states' research programs, as well as those of the Federal Highway Administration, NHTSA, the National Cooperative Highway Research Program, the American Automobile Association's Foundation for Traffic Safety, the Insurance Institute for Highway Safety, and others.

The incentives to implement this technology will be its flexibility in deployment to different types of locations and its ability to record and automatically identify trajectories of multiple vehicles, making it possible to measure the safety performance of locations such as intersections. Once the initial technical challenges have been overcome (mainly by using state-of-the-art technology and the latest tracking algorithms), wide-scale implementation can follow. A growing number of companies and products use this type of video image processing technology for simpler applications in traffic management and incident detection. The SHRP 2 project will set benchmarks for the development of new systems that can be used to assess safety performance with accurate trajectory measurements. In the short to medium term, robust research-level prototypes will become available to highway agencies and others interested in site-based safety analysis. These prototypes will use off-the-shelf hardware components (cameras, networking, workstations), with low-volume manufacture of the data acquisition hardware. Software needed

to run the system will also be made available. At this stage, the number of users and programs involved will be somewhat limited. For the longer term, commercial companies are already interested in further developing this type of technology to make it generally available and fully supported for the broader user community. In this context, the project can be seen as a catalyst for a new generation of safety evaluation systems, one that has established feasibility, generates awareness and interest, and sets standards that must be attained or surpassed by future commercial products.

Other Potential Users

The majority of the users of SHRP 2 Safety products are expected to be highway safety practitioners and researchers. Nevertheless, as knowledge of this research becomes more widespread, additional sectors of the highway community are expressing interest in using the data to address other critical issues. For example, highway planners are interested in the route choices made by the volunteers in the safety study. Traffic operations professionals want to see whether the data can help them understand how drivers behave when they travel in work zones or drive past crash scenes. The site-based video tool could even be set up in work zones or near special events to study traffic patterns under these circumstances. In the naturalistic driving study, volunteers' daily driving behavior will be recorded, and these data could be used to generate travel time distributions for repeated trips on the same route. This information, together with data on weather, crashes, or special events, could be used to study the impacts of such events on travel time reliability and possibly the detour choices made by drivers. The data derived from the study could also be used to examine driver behavior and vehicle performance related to air quality, such as cold starts. SHRP 2's Reliability focus area (see Chapter 4) is carrying out a study to determine the feasibility of using data from safety research such as SHRP 2's naturalistic driving study to address some of these other issues.

CONCLUSION

The SHRP 2 Safety program represents the most ambitious driver-centered, system-oriented safety research effort conducted to date. Its main component is a naturalistic driving study involving approximately 4,000 volunteers

over a period of 2 years. This study will yield hitherto unobtainable data on driver behavior and the interaction among driver performance, vehicle performance, and roadway conditions before, during, and after crash events, as well as during near-crashes and normal driving. Crash risks associated with various factors will be determined, and this information will form the basis for better use of existing safety countermeasures and development and application of new countermeasures. Identification of crash surrogates will make evaluation of countermeasures significantly faster and safer. The data that make all this possible will be a major national resource. However, the potential benefits of this SHRP 2 Safety research will not be fully realized without a continued investment of human and financial resources to ensure that this major national resource is made available to users long after SHRP 2 has ended.

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Abbreviations

FHWA	Federal Highway Administration
NHTSA	National Highway Traffic Safety Administration
TRB	Transportation Research Board

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3 Renewal Focus Area

SHRP 2 Renewal program goal: To develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lasting facilities.

The continued mobility demands placed on the nation's highway system mean that renewal work often must be performed while a highway facility remains in service. This requirement introduces significant safety, mobility, and economic concerns. The public demands that the work be done quickly, with as little social and economic disruption as possible, and in such a way as to reduce future interventions to a minimum. The resulting safety, economic, financial, management, environmental, aesthetic, and technological challenges are formidable enough for an individual project; meeting these challenges on a nationwide scale will require the development of an entirely new way of approaching highway renewal.

SHRP 2 RENEWAL RESEARCH

The strategic objectives of the SHRP 2 Renewal focus area address three needs: (*a*) to complete renewal of existing highways quickly, (*b*) to do so with minimal disruption to the community, and (*c*) to produce facilities that are long-lasting. These objectives—often referred to by the shorthand phrase "rapid renewal"—have been achieved under special, high-profile circumstances (see examples in Box 3-1). SHRP 2 Renewal research is aimed at instituting a new way of thinking about highway renewal so that the benefits of rapid renewal can be achieved consistently and systematically rather than

Box 3-1

EXAMPLES OF RAPID RENEWAL PROJECTS

Contractor Incentives Accelerate Construction Project in California

On Sunday, April 29, 2007, a gasoline tanker traveling through the "MacArthur Maze" interchange on westbound 80 to southbound 880 toward San Jose, California, overturned and caught fire. The intense heat caused the steel frame of the freeway to soften, and the eastbound 580 connector above collapsed onto the 880 connector, forcing closure of two major arterials in the interchange.

The governor issued an emergency declaration the same day that allowed for streamlining of public contracting and permitting codes and provided emergency funding to enable repair operations to begin immediately. The California Department of Transportation estimated that repairs to the damaged section of the MacArthur Maze would cost $5.2 million. For every day short of the June 26, 2007, deadline, the agency offered a $200,000 bonus, up to $5 million total. The highest bid was $6.4 million. The construction firm C. C. Myers of Rancho Cordova won the job with the low bid of $867,075. The company had a plan to get the job done rapidly enough to earn the entire bonus.

Crews were on the job less than an hour after the contract was signed. Work continued 24 hours a day in 12-hour shifts. The first vehicles traveled on a repaired interchange on the evening of May 24, approximately 25 days after the incident had occurred.

Full Road Closures Reduce Project Duration in Several States

In certain circumstances, full road closure can be less disruptive than attempting to maintain traffic through a construction area:

- The Delaware Department of Transportation (DOT) rehabilitated a 6.1-mile section of roadway between Wilmington, Delaware, and the Pennsylvania state line. The project included rehabilitation of pavement, bridges, the drainage system, lighting and safety features, and 10 interchange ramps. Full directional road closures were used to reduce the construction time from 2 years to 185 days.
- The Oregon DOT used full directional closures when it repaved the Banfield Freeway in Portland. The use of full closures reduced the time for the paving portion of the project from 32 nights to 2 full weekends.
- The Michigan DOT used full closure to speed construction and improve safety when it rehabilitated part of the Lodge Freeway in Detroit. The use of full closure reduced the construction time from 6 months to 53 days.

SOURCES: FHWA 2007a; FHWA 2008a.

only on isolated special projects. This new way of doing business is built on more collaborative relationships and decision making; better integration of management, planning, design, construction, and maintenance; and more synergistic use of technologies and methods so that optimal benefits can be realized from complementary sets of innovations.

Benefits

The benefits of rapid renewal are many. The most immediate benefit is reduced disruption for users of the roadway, as well as adjacent businesses and property owners. This benefit can be realized through avoidance of delays from construction, a decrease in the time a facility may experience reduced capacity or local businesses may be inconvenienced, and less construction noise for adjacent businesses and property owners. Less delay for trucks means reduced freight transportation costs and overall benefits to the economy. In addition, more collaborative decision making may contribute to streamlined project delivery. Performance specifications and nondestructive testing reduce the number of people required to ensure high-quality results; resources previously devoted to quality verification can be redirected to building and maintenance. Smoother pavements promote fuel efficiency (Amos 2006) and reduce noise (Wayson 1998). Renewal using recycled materials benefits the environment by avoiding the additional energy consumption associated with the production of new materials. Shorter construction times reduce exposure to work zone crashes, which killed more than 1,000 people in 2005 and injure more than 40,000 each year (FHWA 2007b). In the long run, the largest benefit will come from an increase in the life of highway assets. Bridges and roads that last longer mean billions of taxpayer dollars saved, as well as less frequent disruption from future renewal activities.

Tactics

Renewal time in the field can be defined as the time it takes to complete those on-roadway construction activities that affect traffic flow and the communities and businesses that rely on the roadway for services. Rapid renewal applies innovative approaches or technologies to reduce the time traditionally allocated to these on-roadway activities, thereby minimizing

the impact on users and communities. SHRP 2 Renewal research is organized around seven tactics that are roughly aligned with the three strategic objectives of rapid renewal. These tactics are described below. The specific research projects included under each tactic are listed in Appendix B.

Tactic 1: Perform Faster In Situ Construction

This tactic addresses high-intensity construction projects performed on a compressed schedule. Carrying out such projects is not just a matter of working harder and faster to build a road, but of employing innovative technologies to replace the old ways of doing things and adapting roadway and bridge designs to optimize the use of these technologies. It also means completing preliminary engineering tasks, such as the timely relocation of public utilities, before construction begins. Utility relocation is one of the major causes of construction delay. This tactic also addresses the development of techniques and guidelines better suited to renewal construction, such as performance specifications and rapid nondestructive testing.

Tactic 2: Minimize Field Fabrication Effort

This tactic involves approaches that can minimize the amount of fabrication performed at the project site, thus speeding up the on-site construction phase of the work—the part that actually affects traffic. The SHRP 2 Renewal plan will address prefabrication, modular construction, and innovative installation strategies for bridges and pavements as part of this tactic. Rapid construction systems such as modular pavements and prefabricated bridges or bridge elements can help reduce traffic disruption by permitting elements of pavements, bridges, and other roadway infrastructure to be built off-site and then installed in assembly-line fashion. Off-site construction also permits more intensive quality control, thus improving the level of performance and longevity of the highway infrastructure.

Tactic 3: Perform Faster Construction Inspection and Monitoring

To be rapid, a renewal project must be built and accepted quickly before being opened to the public. This tactic addresses the need for innovative, high-speed inspection and monitoring processes that can ensure that the desired quality and performance are obtained.

Tactic 4: Facilitate an Innovative and Equitable Contracting Environment

One of the main challenges facing agencies on rapid renewal projects is the vastly accelerated pace of construction. Decisions that once took days to make must be made in hours, or even minutes. Such decisions must also be made in concert with the construction contractor or construction management consultant. This need for partnership demands a reassessment of risk sharing among the partners. Research conducted in support of this tactic focuses on developing performance-based specifications that afford the contractor greater construction control while managing agency risk, as well as on reexamining the allocation of risk inherent in the special nature of accelerated construction.

Tactic 5: Improve Customer Relationships

Planners of renewal projects must accommodate the needs and rights of utilities and railroads that share roadway rights-of-way to keep renewal projects on schedule and budget. SHRP 2 research will provide new, streamlined permitting and relocating processes that allow for the timely and efficient progression of renewal projects for agencies, utilities, and railroads. The research will also produce recommendations for the institutional and procedural changes necessary for implementation of those processes.

Tactic 6: Design and Construct Low-Maintenance Facilities

Producing long-lasting facilities not only reduces ownership costs but also significantly reduces disruption to users over a facility's life cycle. This tactic addresses requirements for designing new or rehabilitating existing facilities so as to reduce the frequency and magnitude of future maintenance activities. The goal is to integrate performance-related designs with innovative construction processes that result in long-life solutions. The products of research under this tactic will narrow the gap in professional practice between design life and actual performance.

Tactic 7: Preserve Facility Life

Extending facility life through proactive preservation activities demonstrates good stewardship of the public's investment while significantly reducing disruption. This tactic focuses on techniques that can be used to

preserve the life of existing facilities in good condition, thus extending the periods between major reconstruction efforts. Research under this tactic will yield products needed to achieve the preservation of roadways that carry high traffic volumes.

PROMISING PRODUCTS, AND POTENTIAL USERS, INCENTIVES, AND BARRIERS

The projects carried out under Renewal research will yield many products that fall into two general categories: technology and project delivery. Products in the technology category include materials, equipment, designs, and other tools for directly carrying out the renewal work. Products in the project delivery category support the three objectives of the Renewal focus area by addressing construction and asset management, quality control, and institutional arrangements between transportation agencies and their many partners. Products under each category are described below.

Technology Products

Many of the Renewal technology products relate to the road infrastructure itself. For example, several projects deal with pavement technologies. Modular pavements can greatly increase the speed of pavement renewal. Composite pavements can contribute to long-lasting roadways by exploiting the specific advantages of different pavement materials. Renewing existing pavements in place can also speed the renewal process and produce longer-lasting facilities. SHRP 2 will develop pavement systems, design guides and procedures, model specifications,[1] construction procedures, and training materials to support these pavement innovations.

Bridge-related technologies form another major category of SHRP 2 Renewal products. Two research projects are aimed at developing bridges with service lives of 100 years or more. The research will refine bridge designs to extend the service life of those bridge systems, subsystems, and components that typically deteriorate most quickly. By addressing both the

[1] SHRP 2 is not a standards-setting or specifications authority. The research will produce scientific and technological information that such authorities can use to produce formal standards and specifications.

overall structure and its components, a design can be optimized to achieve a long life for the entire facility. A number of innovative bridge technologies already exist, such as modular prefabricated bridge decks and other components that can facilitate rapid construction and long life (see Box 3-2). However, use of these innovations requires some modifications of standard design approaches and new bridge designs that are more compatible with existing innovative construction techniques and technologies. Needed as well are new construction techniques and technologies that are compatible with existing and potential new bridge systems. In general, optimization of designs and materials contributes to long life, but current designs do not reflect constructability, material performance, and in-service performance considerations to the extent necessary to achieve this strategic objective. SHRP 2 will develop design procedures, standard plans, design examples, contracting tools, and training materials to facilitate the use of promising bridge innovations.

While pavement and bridge technologies may be the most obvious elements of highway renewal, other less visible elements are just as important. The condition of soil and foundations for bridges and pavements is critical to rapid construction and long-lived facilities. SHRP 2 will study existing materials and technologies for soil improvement, rapid embankment construction, and pavement stabilization, and it will develop guidelines and design procedures, as well as a construction certification program, for use of these technologies. Another hidden element that affects rapid renewal is the presence, location, and type of underground utilities. Discovery of unexpected utilities or incorrect information about their location or type can be dangerous and often results in significant delays as construction must stop until the situation can be resolved with the utility owners. SHRP 2 is investigating the state-of-the-art of technologies that can be used to locate and characterize underground utilities and will produce guidelines and training materials for their application.

Soils and utilities are not the only hidden factors relevant to rapid renewal. Designers want to know the current condition of existing facilities—for example, whether steel-reinforcing bar has deteriorated or whether there are voids in a concrete pavement—to determine the type of renewal required. In addition, during construction and after a facility has been renewed, the quality of materials and workmanship must be determined—for instance, whether

Box 3-2

ACCELERATED BRIDGE TECHNIQUES

Innovative materials, equipment, and techniques can significantly accelerate bridge renewal and provide longer-lasting structures. Prefabrication of bridges or bridge elements, for example, saves time by reducing work performed at the construction site. The result is reduced traffic disruption, improved safety, reduced impact on other transportation modes (railroads or waterways beneath the bridge), less impact on wetlands, less noise, and shorter duration of adverse impact on local businesses. Prefabrication off-site in a controlled environment can improve constructability by reducing impacts of weather and can enhance construction quality by ensuring more consistent materials and procedures. Standardization of identical components can reduce initial construction costs, and higher quality lowers life-cycle costs. The following are examples of the use of prefabrication and other innovative approaches to bridge renewal:

- Utah is the first state DOT in the country to be transitioning to accelerated bridge construction (ABC) as standard practice. Utah's family of ABC products includes standards for the use of multiaxle computer-controlled platform vehicles, called self-propelled modular transporters (SPMTs), to remove and install bridges. In summer 2008, Utah replaced a dozen bridges on and over Interstate highways, in each case resulting in only days of impact to motorists. Each superstructure was constructed adjacent to the site and then quickly driven into final position on SPMTs (AASHTO TIG 2008; Utah DOT 2008).
- The George P. Coleman Bridge in Yorktown, Virginia, is the largest double-swing-span bridge in the country. By 1995 the number of vehicles crossing the bridge had doubled since it was built, and the movable spans needed repair. A wider replacement bridge was built nearby, and the six spans were barged to the site complete with roadway striping, traffic railing, and light poles. The existing bridge was dismantled and the new bridge erected in just 9 days (FHWA 2008b).
- The deck of the historic Lewis and Clark Bridge on Route 433 between Washington State and Oregon was completely replaced with no impact on peak period traffic through the use of SPMTs. SPMTs were used to remove the old bridge deck and install new prefabricated deck panels on the mile-long bridge, reducing impact on traffic and exposure of workers to hazardous conditions (FHWA 2006).
- New Jersey replaced three bridges on Route 1 over Olden Avenue Connector and Mulberry Street in Trenton in three weekends by using prefabricated superstructures. The use of prefabrication allowed the deteriorated decks to be replaced

(continued)

with no impact on peak-hour traffic. These bridges are expected to have a 75- to 100-year life, significantly more than the typical 50-year life of other bridges in the area (FHWA 2006).

- The Belt Parkway Bridge over Ocean Parkway in Brooklyn was lengthened and widened with no lane closures during peak traffic hours through the use of prefabricated bridge components. The entire design–build project was completed in 14 months, including a 3-month winter shutdown. Construction would have taken 3 to 4 years with conventional methods (FHWA 2006).

the pavement has been fully compacted or whether a material has finished curing. The more rapidly quality can be verified, the more quickly the road can be reopened to traffic. Such questions have typically been answered by means of time-consuming destructive sampling and testing: a sample of a pavement is removed and brought to a laboratory for analysis; a sample of new material is set aside for a prescribed number of days and stressed to failure in the laboratory to test its strength. Nondestructive tests that can be applied in the field provide answers more quickly. SHRP 2 will evaluate such tests and perform proof-of-concept research; for technologies that prove worthwhile, test procedures and training materials will be developed.

Project Delivery Products

SHRP 2 products in the project delivery category address barriers to rapid renewal that exist beyond the design and construction activities directly associated with a given renewal project. These barriers relate to management and institutional issues that must be addressed for rapid renewal to be applied more widely. Projects in this area are closely related to those in the technology category. For example, while one technology project addresses technologies that can locate and characterize underground utilities, a project in the project delivery category addresses the broader issue of the relationship between utility companies and highway agencies. The latter research is exploring means of improving communication and decision making between these very different entities to promote cooperation and attainment of the priorities of each. Box 3-3 provides an example of how better coordination of utility relocation can contribute to reduced duration of

Box 3-3

EXAMPLE OF BENEFITS FROM A PROJECT DELIVERY PRODUCT

The Links I Utility Corridor

This project involved relocating the utility facilities of several different companies in advance of the reconstruction of State Road 60 in Tampa, Florida. The project constructed a separate structure, 10 feet wide by 10 feet deep, that housed 12 utilities stacked vertically with staggered horizontal placement, and a separate service road for access and maintenance. The coordinated relocation of utilities reduced the overall duration of the construction project from 7 to 5 years.

SOURCE: www.tfhrc.gov/FOCUS/june07/03.htm.

construction. The products of the research will include a manual of best practices and model cooperative agreements. Similarly, renewal projects often entail coordination with railroads that cross or abut highway rights-of-way. Highway agency–railroad interactions can cause significant delay, yet this is an issue not easily addressed by technology. SHRP 2 is examining ways to improve communication and coordination with railroads to promote mutually beneficial outcomes in dealing with roadway renewal projects. Products of this work will be analogous to those developed in the project related to utilities.

Use of some of the pavement, bridge, and geotechnical technologies described under the technology product category will require additional nontechnological support. For example, the benefits of composite and modular pavements and innovative bridge elements are predicated on their long-term performance. Highway agencies need to know how to specify such performance, as well as how to measure whether it has been delivered. SHRP 2 will provide the data and guidelines needed to develop performance specifications in lieu of the traditional materials and methods specifications used for more common technologies. This move from methods and materials to performance specifications can affect risk allocation among agencies, contractors, and suppliers. SHRP 2 is assessing the shifting allocation of risk and developing guidelines and training materials to aid agencies and contractors in managing project risk effectively.

Frequent episodes of pavement or bridge maintenance can be just as disruptive as construction, particularly on highways with high traffic volume. To exploit the life-cycle benefits of renewal while minimizing disruption, timely and effective preservation activities are needed. SHRP 2 will develop methods and data to help agencies perform life-cycle analyses of long-lived facilities, along with draft preservation guidelines focused on high-volume roads.

A major challenge to implementing the products of the Renewal focus area will be delineating how this wide variety of products can be used together effectively to achieve the objectives of rapid renewal. This is to some extent a question of packaging and communication, but even more of developing tools to help users assess the needs of their own projects and determine the optimal suite of technologies and techniques for their circumstances. The synergistic relationships among technologies need to be identified, and guidelines for combining them strategically must be developed.

Potential Users, Incentives, and Barriers

The foregoing description of Renewal projects suggests a wide array of potential users. Highway agencies at the state, regional, and local levels will be the primary users of most of the products. But even within these agencies there are many different potential users. Pavement and bridge designers, geotechnical engineers, utilities coordinators, construction inspectors, and project managers will use different products at different stages of the renewal process. Incentives for agency personnel to use the products of Renewal research include minimizing traffic disruption; providing better facilities; improving life-cycle costs; streamlining project delivery; and achieving better working relationships with utilities, railroads, and adjacent businesses and property owners. Agency personnel will not assume the risks of innovation unless they develop a high level of trust in the innovation and in those promoting it. Building trust will be key to successful implementation.

Despite the incentives, agencies face significant barriers to innovation. Many innovations that lower life-cycle costs and user costs (by reducing delay) have higher initial construction costs; this is especially true for the first use of an innovation by an agency. Given restricted budgets and pressure to start projects in multiple jurisdictions at once, many agencies may

find it difficult to carry out fewer projects with higher initial costs in a given year. They will need information and resources to articulate the benefits of rapid renewal in terms that are meaningful to the public and to political leaders. They may also need legislative or regulatory changes to allow the use of new approaches—for example, to allow a life-cycle rather than initial low-bid procurement procedure or to utilize an innovation that includes a proprietary element. Agencies will also need training and technical support to guide them through the implementation of innovative approaches. They may need financial assistance as well to cover the delta (additional) costs associated with demonstrating a new technology.

Highway design and construction is a world sharply bounded by standards and specifications. These are the tools with which agencies safeguard the public treasury and secure the public safety. If efforts to implement SHRP 2 Renewal products do not recognize and accommodate the special role of standards, widespread implementation may founder. An intensive effort to develop consensus standards for the application of SHRP 2 Renewal products must proceed among standards-setting organizations in parallel with other implementation activities. As implementation progresses, lessons learned will need to be reflected in the evolution of prototypical or provisional standards.

Another simple but significant barrier to innovation faced by many public agencies is restrictions on travel, sometimes even if the travel is paid for by others. New technologies, such as individual web-based training, webinars, and teleconferences, can help overcome this barrier by providing training remotely. Nevertheless, technology transfer is a people-oriented activity, and the benefits of face-to-face communication and hands-on experience with new technologies cannot be overstated. Local agencies in particular will need active outreach and support. Purchases of new equipment, the development of new specifications and standards, and training all cost money that may not be in agency budgets.

Contractors and suppliers of materials and equipment will use products related to their lines of business; they may be particularly interested in the performance specifications, model contract language, and risk manual. They will be concerned about what the highway agencies will require of them and how it will affect their competitive position. Some may welcome the changes as an opportunity to compete on the basis of quality and speed

provided through innovation. More collaborative approaches can lead to fewer claims. Others may feel threatened by change and require more outreach and support to identify the innovations that will work best in their business model. Effective methods of engaging contractors will include incentives to innovate. The distribution of risk associated with some rapid renewal techniques may result in more risk being borne by the contractor. Distribution of the burden of risk to those most capable of bearing it must be addressed up front by all parties and reflected in contract documents, project compensation, and incentive structures. A strong commitment to partnership between agency and contractor must exist for both parties to move forward successfully in implementing innovations. Both parties will experience a learning curve, and the agency's willingness to share the risk at the outset will facilitate implementation.

Other potential private-sector users include engineering and design consultants. They will also need to learn how to use the new designs and materials, and changes in their internal design and project management procedures may be required.

Utility companies and railroads will be users of the research aimed at promoting coordination and cooperation between these entities and highway agencies. At the heart of this research is the question of incentives for and barriers to cooperation. Utilities and railroads have business objectives that differ from those of agencies that renew roads and highways. Each entity needs to have reason to see itself as a partner in the renewal effort, with something to gain as well as something to contribute.

Local businesses and neighbors will not be direct users of Renewal products, but they will be affected by the use of those products. Outreach to these affected parties should take place early and as often as necessary to keep them fully informed about how renewal will influence their businesses and daily lives. It may be helpful to describe alternative scenarios to highlight the benefits of differing strategies and to solicit their input into decisions closely affecting them.

Other important potential users of Renewal products are teachers, professors, and researchers. For rapid renewal strategies to take hold as ordinary operating procedures, universities will have to incorporate them into their highway engineering and construction management curricula. Training and certification programs for engineering technicians and construction

workers will also need to incorporate the new technologies. Researchers will need to direct their investigations toward rapid renewal approaches, building on and going beyond what has already been developed.

CONCLUSION

Incorporation of the SHRP 2 Renewal research products into standard business practices will be challenging but rewarding. What were once viewed as highly innovative measures employed for use only on special projects will become the normal way of doing business. Stakeholders will modify the ways they think and act, and possibly the ways their organizations are structured. The highway transportation community is large, complex, and generally risk averse. Small innovations are sometimes easier to implement than those that require a paradigm shift. Time and dedicated resources will be required to create an environment in which the highway community will embrace innovations that promise long-term benefits and may require a substantial change in organizational behavior and business practices. SHRP 2 Renewal products must be applied systematically over an extended period of time for such change to take place.

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Abbreviations

AASHTO TIG	American Association of State Highway and Transportation Officials Technology Implementation Group
FHWA	Federal Highway Administration
Utah DOT	Utah Department of Transportation

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4 Reliability Focus Area

SHRP 2 Reliability program goal: To provide highway users with reliable travel times by preventing and reducing the impact of nonrecurring congestion.

Congestion seems to be like the weather—something we talk about but cannot do much to change. We avoid it if we can, endure it if we must. Congestion is a complex phenomenon; its interrelationships with the economy, safety, and the environment are not always straightforward. It is defined differently in urban versus nonurban areas. It may be described as "gridlock" in one city but may be bearable evidence of economic growth in another. Congestion is often a matter of perception: different travelers perceive it in diverse ways depending on its impacts, including the perceived cost or penalty for being delayed, and on the importance the traveler attributes to a particular trip. Congestion generally takes two forms: *recurring*, or everyday peak-hour congestion, and *nonrecurring*, or the seemingly unpredictable congestion that occurs at unexpected times or places. Nonrecurring congestion causes highway users to regard the highway system as "unreliable."

The complexity of congestion calls more for a dynamic operational perspective than for the static infrastructure perspective traditional to highway engineering. Addressing the problem also requires the active participation of both public- and private-sector entities. Solutions must tap a suite of strategies, including design, construction, system operation and management, pricing, modal shifts, land use, and many other factors. New concepts and vocabulary must be employed to reflect the probabilistic and systemic nature of the phenomena associated with congestion, necessitating in turn training

and education of those responsible for planning, programming, operating, and maintaining the highway system. Political leaders need to understand how highway operations, as well as new construction and maintenance, affect congestion and consequently how suboptimal resource allocation decisions can hamper a comprehensive approach to congestion mitigation.

SHRP 2 RELIABILITY RESEARCH

SHRP 2 addresses congestion in two strategic focus areas. The Capacity focus area, discussed in the following chapter, addresses the need for new physical capacity to deal with recurring congestion and explicitly includes economic, environmental, and pricing aspects of the issue. The Reliability focus area, described here, addresses a particular operational characteristic of highway systems that is related to nonrecurring congestion: travel time reliability. From the highway user's perspective, travel time reliability means the extent to which one can depend on completing a given trip within a consistent, predictable length of time. More specifically, travel time reliability is the probability or percent of time that a person or goods shipment will arrive on time (or within a time window) for a particular type of trip, departure time, origin and destination, and environmental setting. When travel times are not reliable, travelers frequently find themselves late unless they build additional buffer time into their trips. For example, one may leave earlier to ensure arriving on time for an important appointment or to catch a flight. This buffer time could have been spent on other activities and could actually be spent waiting at one's destination if the time was not needed in the end.

SHRP 2 research is aimed at improving travel time reliability by addressing the nonrecurring portion of the congestion problem. The relatively unpredictable events that are responsible for nonrecurring congestion can be categorized as follows:

- *Traffic incidents:* This category covers a number of different types of events. Crashes are a common example; when a crash occurs on a roadway, at least one lane of traffic is typically blocked by the vehicles involved in the crash. Often, additional lanes are blocked by police, fire, and emergency medical vehicles and equipment. Even if the crash occurs off the road or has been moved to the shoulder, through traffic must slow down for safety

reasons or chooses to slow down out of curiosity. Other types of incidents can also block a portion of the roadway or provide rubbernecking opportunities. Such incidents may include police activity, broken-down or abandoned vehicles, debris on the roadway, and cargo spills (including spills of hazardous material, which require special safety and cleanup procedures).

• *Work zones:* A heavily used and aging infrastructure requires substantial maintenance and rehabilitation, much of which must be carried out while the facility is still in use. Work zones block lanes and sometimes require reduced speeds and modified traffic patterns, all of which can add to travel time and congestion.

• *Weather, environmental, and emergency impacts:* Rain, snow, ice, fog, and sun glare can often slow traffic even when they do not contribute to crashes or breakdowns. Even with efficient plowing, snow can reduce the number or width of lanes in locations that lack adequate space to store plowed snow. Heavy rains or poor drainage can leave portions of low-lying roads impassable during and after a storm. Hurricanes, tornadoes, wildfires, or terrorism threats may call for emergency evacuation or closed roads.

• *Special events:* Football games, parades, demonstrations, marathons, motorcades of dignitaries, and many other sporting and civic events can have significant impacts on local traffic. If drivers are not forewarned about such events, they can be surprised to find their trip's duration lengthened.

SHRP 2 focuses on nonrecurrent congestion and travel time reliability for three reasons. First, approximately half of the delay experienced by highway travelers is characterized as nonrecurring or caused by nonrecurring events (Chin at al. 2002). Reducing the impact of incidents that cause nonrecurring congestion can have a significant effect on reducing overall congestion and travel delay. Second, travel time is something highway users understand. They know what it means for travel times to be highly variable and what impact this variability has on their personal and professional lives. Being late because a trip took longer than would reasonably have been predicted can mean missing an appointment or a plane, losing a client, or disappointing a loved one. Shippers who operate on a just-in-time basis pay a penalty for deliveries that occur outside of a narrow window, whether too late or too early. Workers know they cannot regularly be late for their jobs if they wish to remain employed. Parents picking up children

at day care may be charged for arriving late. The third reason for focusing on travel time reliability is that it is amenable to existing and emerging management and technological tools. In 2005, for example, traffic incident management programs reduced congestion in 437 urban areas by 130 million hours, saving $2.5 billion (TTI 2007).

While the terms "recurrent" and "nonrecurrent" congestion have become somewhat conventional among highway operations professionals, they are not truly independent phenomena. Incidents such as those cited above often take place during periods of recurrent congestion, which increases their impact. The baseline traffic volume on a road influences the severity of an incident's impact on travel time: the closer to capacity a highway facility operates, the more sensitive it is to such perturbations as crashes, rubbernecking, and blocked lanes. Table 4-1 indicates the percentage of lost throughput capacity on a roadway that is due to incidents that block one or more lanes or the shoulder. Design characteristics of a road system—such as traffic signal timing, the presence or absence of shoulders, and lane drops[1]—also influence the severity of nonrecurring incidents.

Managing incidents to reduce their impact on the variability and unpredictability of travel times requires a multifaceted approach. SHRP 2 has identified four areas in which research could make a significant contribution:

• *Data, metrics, analysis, and decision support:* This area encompasses the following questions: How can reliability best be defined, measured, and monitored? How effectively do various strategies improve reliability? How can these strategies be used by agencies to guide actions and investments aimed at reducing nonrecurring congestion?

• *Institutional change, human behavior, and resource needs:* In any complex system, the human participants are a critical component. This area relates to how transportation agencies can evolve to reduce nonrecurring congestion and mitigate its impact through highway operations. It also addresses how transportation agencies and other organizations involved in incident management and response can collaborate more effectively. In addition, it deals with training needs and driver behavior.

[1] A lane drop is a reduction in the number of traffic lanes on a road, usually at an intersection, interchange, or dividing point.

TABLE 4-1 PERCENTAGE OF LOST THROUGHPUT CAPACITY DUE TO LANE OR SHOULDER BLOCKAGE

No. of Lanes	Shoulder Blocked (%)	Lanes Blocked		
		1 (%)	2 (%)	3 (%)
2	19	65	100	NA
3	17	51	83	100
4	15	42	74	87
5	13	35	60	80
6	11	29	50	74

NOTE: NA = not applicable.
SOURCE: FHWA data reported in WSDOT 2007.

• *Incorporation of reliability into planning, programming, and design:* This area involves arming transportation professionals with the technical and policy tools needed for effective management of nonrecurring congestion. The data, tools, and information about institutional and human behavior derived from research in the first two areas above will be consolidated and incorporated into the planning, programming, and design processes of transportation agencies.

• *Future needs and opportunities:* The research in this area will focus on fostering innovative thinking that can form the foundation for long-term reductions in nonrecurring incidents and improvements in travel time reliability.

PROMISING PRODUCTS, AND POTENTIAL USERS, INCENTIVES, AND BARRIERS

The products of SHRP 2 Reliability research are many and diverse, as are the potential users of those products. Ideally, the products would be implemented in an integrated fashion. That is, transportation organizations would simultaneously apply institutional, analytical, planning, operational, design, and management strategies to leverage their synergistic relationships and would coordinate this implementation across user groups (see Box 4-1 for an example of such an integrated approach). For clarity of exposition, however, this section describes the products of SHRP 2 Reliability

Box 4-1

MARYLAND CHARTING THE COURSE

The State of Maryland's incident management program is among the most advanced in the nation. It is part of a larger organization known as the Coordinated Highways Action Response Team, or CHART, a joint effort of the Maryland State Highway Administration, the Maryland Transportation Authority, and the Maryland State Police. In addition to managing traffic incidents, CHART deals with weather-related emergencies, construction-related road closures, and other issues associated with highway operations. CHART operates a Statewide Operations Center near Baltimore–Washington International Thurgood Marshall Airport. This facility works in conjunction with several smaller regional traffic operations centers located throughout the state.

The CHART program may have prevented as many as 766 secondary incidents in 2001 through its prompt clearing of primary incidents, according to experts at the University of Maryland. Researchers estimate that the 25.80 million vehicle hours of delay "eliminated" by the program in 2001 saved 4.35 million gallons of fuel and kept 4,027 tons of vehicular emissions out of the air.

SOURCE: AASHTO 2004.

research first, and then the potential users of those products and the incentives for and barriers to implementation.

Products

The products to be developed under SHRP 2 Reliability research can be grouped into the four areas described above. A list of Reliability projects and corresponding products is provided in Appendix B.

Data, Metrics, Analysis, and Decision Support

Research in this area will identify data types, measurement methods, and analysis tools and will develop an archive of travel time data, performance measures, and operational strategies. The archive will support transportation agencies at all levels in monitoring travel times and related reliability measures, developing and using performance measures and models, and evaluating actions aimed at controlling and mitigating nonrecurring con-

gestion. A guidebook will help practitioners establish reliability monitoring programs. Technical relationships between mitigation measures and performance will be developed so that practitioners will have a basis for making informed choices. Mechanisms for incorporating reliability estimation into planning and operations models will be developed as well.

Institutional Change, Human Behavior, and Resource Needs

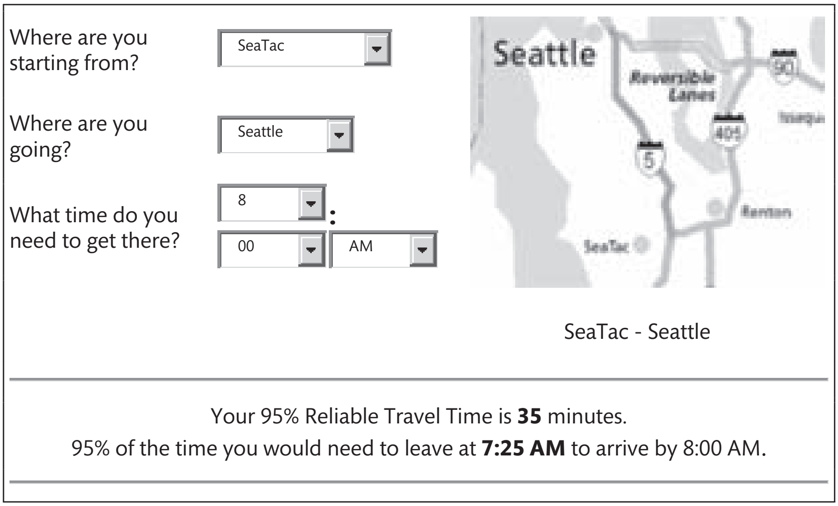
In the area of highway operations and incident management, the actors are many and diverse: managers of highway agencies and their technical staff; the political leaders who provide authorization, budgets, and oversight; drivers; police, fire, and emergency medical personnel; tow truck operators; maintenance and construction workers; businesses; sponsors of special events; and weather forecasters. Reducing congestion related to nonrecurring events will require significant modifications of the internal organizational structures and business practices of transportation and public safety agencies. Impact mitigation will require new organizational systems, practitioner interactions, and effective communications. Research in this area will provide information to guide agency managers and practitioners in making business process and institutional changes in support of improved reliability. Managers will find guidance for effectively disseminating travel time reliability information in several alternative formats so that road users can make informed driving decisions. Box 4-2 provides an example of a format used by the Washington State Department of Transportation.

Case studies from both domestic and international transportation organizations and from nontransportation industries, together with insights gained from research on organizational behavior, are identifying the most effective practices and organizational structures for managing 24-hour facilities such as highway systems. Focusing specifically on how these approaches can improve incident management and travel time reliability, SHRP 2 research in this area will examine ways of inculcating an operations orientation in the institutional culture of transportation agencies to strengthen their capacity to deal with nonrecurring congestion. A focused training program is being developed to ensure that all professionals who respond to highway incidents—transportation staff, firefighters, police, emergency medical personnel, tow truck operators, material spill responders—are well versed in the state of the art of safe and efficient incident response procedures

Box 4-2

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION ONLINE TRAVEL TIME CALCULATOR

The Washington State Department of Transportation provides an online tool travelers can use to calculate their commute times. The tool uses travel time data to estimate the "worst case" travel time scenario. Commuters can expect to arrive at their destination within the calculated time 95 percent of the times they make this trip at the chosen time of day; that is, they can expect to be on time for work 19 out of 20 working days a month if they allow for the calculated trip duration.



SOURCE: WSDOT 2008.

in traffic environments. Driver behavior is being addressed in two ways. One project addresses travel time information, a key need of road users, by examining the accessibility and utility of traveler information mechanisms and technologies and assessing the system performance effects of the improved traveler information they provide. The second research effort will use video and other data collected in past studies and SHRP 2's Safety field study (see Chapter 2) to learn how drivers behave in work zones or in the vicinity of crashes, special events, or other incidents. Results from these

driver-behavior studies will lead to better traffic management and more effective communication with drivers.

Incorporation of Reliability into Planning, Programming, and Design

Planning, programming, and design processes are key tools used by transportation agencies to improve traffic conditions and reduce and mitigate nonrecurring congestion. Currently, no technical procedures exist with which to incorporate mobility and reliability performance measures into the transportation investment process; as a result, the effects of short- and long-term strategies addressing improved reliability on traditional capital expenditures cannot be determined. Similarly, the effects of alternative design features that can improve reliability have not been fully evaluated, and those that have been are not included in design manuals.

SHRP 2 research in this area addresses the need for improved tools to identify and evaluate the effectiveness of infrastructure and operational countermeasures and to quantify the impacts of nonrecurring congestion on overall highway capacity. The research will link changes in performance measures to individual reliability improvement strategies so the effectiveness of those strategies in reducing congestion can be considered fairly as a substitute for or supplement to infrastructure-based capacity enhancements in the transportation planning and programming process. The research will include pilot studies of the procedures in a number of agencies. In coordination with the work undertaken in the Capacity focus area of SHRP 2 (see Chapter 5), travel time reliability will be included among the factors considered in the highway planning and programming process. Reliability performance, costs, and effectiveness will be incorporated into the key steps that lead to decisions about how the transportation system evolves and is operated. SHRP 2 is studying highway design features—such as crash investigation sites, median crossovers, and wide pavement shoulders—to assess their costs and effectiveness in managing incidents to reduce travel time variability. Many such features are currently in use but not included in standard design guides because of perceived high costs and a lack of data on potential cost savings. Other designs used in countries outside of the United States will be evaluated as well. An example is active traffic management, which combines lane control, variable speed limits, hard shoulders, and accident investigation sites so that highway system managers can control traffic flow both laterally and

longitudinally (see Box 4-3). Results of these analyses will be used to develop nonrecurring congestion factors for the *Highway Capacity Manual* and the *AASHTO Policy on Geometric Design of Highways and Streets*—standard reference materials for highway designers. Turning research results into practical guidance that meets the requirements of these design documents is essential to influencing actual highway designs.

Future Needs and Opportunities

The research described thus far is focused largely on making significant improvements in the short term, taking much of the current highway environment as given. However, many technological, social, and institutional

Box 4-3

M42, WEST MIDLANDS, UNITED KINGDOM

On September 12, 2006, motorists on the M42 in the West Midlands, United Kingdom, were the first in the country to be able to drive on the hard shoulder during busy periods as part of a scheme aimed at cutting congestion. The scheme, called active traffic management, is in effect between junctions 3A and 7 and uses electronic signs to direct drivers to use the hard shoulder during times of peak congestion. Together with variable speed limits, which help smooth the flow of traffic, the scheme has been highly successful in reducing congestion on the M42.

Safety was of critical importance during the design of the scheme. Emergency refuge areas are available at regular intervals to provide motorists with a safe place to stop in the event of a problem with their vehicle. These refuge areas are linked by telephone and closed-circuit television camera to the nearby regional control center. The Highways Agency also worked closely with emergency services to enable them to access the motorway in the event of an incident. Available to staff in the Highways Agency control room are more than 200 cameras on the 11-mile stretch, allowing them to easily spot any incident as it occurs. They can then close an individual lane or lanes by displaying a red "X" on the electronic sign above each affected lane. Taking this action protects the vehicles involved in the incident while clearing the lane to allow access by emergency vehicles.

Compared with road widening, active traffic management is significantly more cost-effective but provides comparable benefits. The benefits include increased capacity, reduced travel times, greater travel time reliability, lower emissions, and lower fuel consumption.

developments are occurring and will continue to emerge; transportation agencies must be prepared to conduct highway operations in new environments and even to create these environments. Research in this area is focused on longer-term, more innovative thinking. One project will define user requirements, performance standards, and present and future concepts of operations to provide agencies with guidance on the best alternative operations strategies for improving travel time reliability. A second project will develop a portfolio of innovative ideas, supported by accompanying proofs of concept, aimed at improving reliability. The intent is to undertake several small experiments or pilot studies to explore innovative ideas deemed promising for future application.

Potential Users, Incentives, and Barriers

The ultimate beneficiaries of the products emerging from SHRP 2 Reliability research will be commercial highway users, bus operators, and individual motorists. Implementation of the majority of these products will lie in the hands of those agencies responsible for active and safe operation of the nation's highways. These users of Reliability products can be divided into four broad groups according to the scope of their interest: (*a*) leaders of transportation agencies are concerned primarily with strategic issues related to transportation and its role in the economy and society; (*b*) technical staff of transportation agencies are focused on delivering transportation programs and services to their customers within legal, regulatory, and financial constraints; (*c*) nontransportation professionals with some relationship to transportation operations usually have very different scopes of responsibility, such as law enforcement, firefighting, or management of a special event venue; and (*d*) researchers and analysts are interested in understanding transportation operations and in developing innovative approaches to meet operational challenges.

Leaders of transportation agencies represent an important user group. Support for reducing congestion by managing nonrecurring incidents must come from directors of state and local transportation agencies, who in turn must convince political leaders to provide the necessary resources. Transportation leaders are potential users of a small but critical set of products: business process and institutional structures for travel time reliability and incident management, and performance monitoring systems. Incen-

tives for the implementation of SHRP 2 Reliability products by these users include providing better service to their customers, getting the most out of existing infrastructure through better management of operations, justifying resource requests, and basing organizational decisions and priorities on better information. On the other hand, barriers to implementation for this group can be formidable. These are busy individuals; they may find it difficult to devote the time required to delve into the concepts and benefits of better incident management. There are few if any quick fixes for a complex system. Benefits will take time to accrue and may be experienced to varying degrees in different parts of the highway system. In competition for limited resources, the building of new facilities often has an edge over management of operations because construction of new highway capacity appears to provide a more direct solution to congestion. Although new construction is sometimes the right approach, agency leaders may feel pressured to focus resources on building even when operations techniques could provide a more cost-effective answer.

Technical staff of transportation agencies are the largest group of potential users of Reliability products. Within this group are subgroups with particular technical roles that correspond to different products. Planning staff will be able to use the planning models that incorporate travel time reliability factors developed under SHRP 2. Design staff and the consultants who work with them will use the *Highway Capacity Manual* and the *AASHTO Policy on Geometric Design* as modified by results of the SHRP 2 research. Operations and planning staff will be able to utilize the travel time monitoring systems designed under the program. The results of the driver behavior research will be useful to traffic engineers and public safety officials in improving traffic control for work zones and special events; incident managers will be able to develop better response techniques in such areas as vehicle placement and lighting. Incident response professionals would also benefit from joint training in safe and efficient procedures at incident scenes.

Highway agency staff members are not the only transportation professionals concerned with travel time reliability. Managers and operators of bus systems have a large stake in this aspect of highway performance. Bus scheduling depends on reliable expectations regarding travel time on specific routes. Nonrecurring events adversely affect bus riders as much as automobile drivers; bus riders want timely and accurate information about

travel times in terms of bus arrivals at their origin and destination stops. Private-sector freight haulers are concerned about travel time reliability as well and are potential users of SHRP 2 Reliability analysis and planning products.

Despite the technical differences among these potential users, they share similar incentives and barriers to implementation of SHRP 2 products. Their main incentive is better quality in their respective areas of work and more efficient use of resources as a result of more solid foundations for decisions and better analysis, planning, and design tools. Field staff will experience greater safety and better coordination because of clear, consistent guidelines. Nevertheless, there are barriers to implementation. Trying any new technology or changing established procedures can be difficult and risky. Demonstrations and pilot tests using innovations on real projects will be necessary to convince these professionals that the innovations are more than just a good idea. Personnel constraints pose another major barrier. Most transportation agencies have been experiencing declining staff levels. Employees are often so busy that they find it extremely difficult to take time to be trained in new methods. However, a wise manager will often consider the potential benefits of innovation to be more than adequate justification for time spent in training. A more difficult challenge occurs when an innovation requires such a different skill set that new employees are needed. Some agencies will face such a need for new staff and be unable to obtain the authorization to make these hires.

Another significant barrier is lack of data. Effective use of SHRP 2 products, such as programming and planning models or systems for monitoring travel time reliability, will require jurisdiction-specific data so that accurate analyses can be performed. Although states collect a great deal of data on their highway systems, they do not all collect all the data needed for effective system management because of resource constraints. Local transportation agencies typically are even more resource constrained when it comes to personnel, training opportunities, and data collection. SHRP 2 research products will include advice on how to work with limited data sets. On the positive side, data are increasingly available for purchase from the private sector. Perhaps the largest potential barrier to implementation for the technical staff of transportation agencies is a lack of high-level awareness of the benefits of operational management approaches to congestion mitigation—

a point discussed above in identifying transportation agency leaders as the first set of potential users of SHRP 2 Reliability products.

Although the barriers described above are formidable for state transportation agencies and even more so for local agencies, the incentives for these agencies to improve travel time reliability are significant given the impact of nonrecurring congestion in rural and urban areas both large and small. In urban areas, well over half (58 to 67 percent) of all congestion can be attributed to nonrecurring congestion; in rural areas, this figure rises to 98 percent (see Figure 4-1).

Management of incidents and special events as a strategy for congestion mitigation involves an array of *nontransportation professionals* mentioned earlier, including police, firefighters, tow truck operators, emergency medical personnel, and special event sponsors. The effectiveness of some Reliability products will be highly influenced by the degree to which these other groups are involved in their implementation. The most salient example of this point relates to the incident response training that SHRP 2 will produce. This project is developing training for all potential incident responders—police, firefighters, emergency medical personnel, tow truck operators, and transportation agency personnel—in a consistent set of

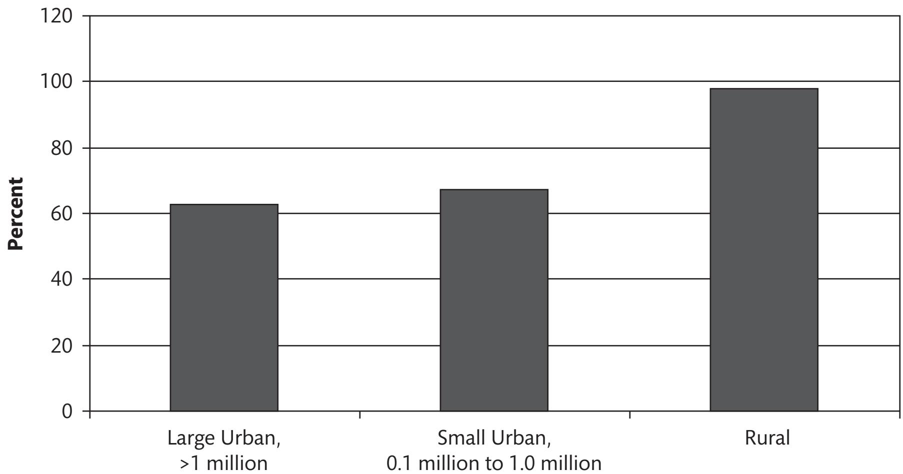


FIGURE 4-1 CONTRIBUTION OF NONRECURRING CAUSES TO CONGESTION IN URBAN AND RURAL AREAS.
Source: Adapted from Lockwood 2005.

procedures designed to promote safety and operational efficiency. The training is not intended to replace specialized training received by each of these groups but to supplement that training by focusing on behaviors and activities common to all responders, such as proper traffic control, use of reflective gear, and safe behavior near high-speed traffic. The need for this training is clear when one considers that in 2006, 43 percent of fatalities among police, firefighters, and emergency medical personnel resulted from transportation incidents (BLS 2006, Table A-6). Indeed, improved responder safety is the main incentive that incident response groups will have to participate in the training produced by SHRP 2. Public safety professionals are also interested in effective incident management to reduce the risk of secondary crashes, which account for 14 to 18 percent of all crashes and cause 18 percent of freeway deaths (studies cited by Zhou and Sisiopiku 1997).

Nontransportation practitioners may become involved as well in implementation of the results of the SHRP 2 research on institutional structures and future concepts of operations. In both of these areas, greater interaction and coordination are envisioned among public and private organizations to improve management of incidents and special events so as to reduce nonrecurring congestion. Better interaction among responders can also improve working relationships when emergencies unrelated to traffic incidents occur.

Finally, private-sector providers of traveler information should find useful the results of the SHRP 2 research on how drivers use traveler information. The main barrier to implementation of SHRP 2 Reliability products by nontransportation professionals will be the diverse institutional cultures involved and the difficulty of getting these disparate groups to cooperate toward a common goal. Conflicts related to operational authority can arise among police, fire, medical, and transportation organizations. Each group may also assume that there is nothing to learn from outside its own community. In some cases, there may even be laws or regulations that limit certain forms of cooperation. Mechanisms to facilitate the necessary interorganizational coordination and cooperation need to be developed.

The SHRP 2 Reliability focus area will produce an archive of data on travel time reliability and the effectiveness of methods for improving reliability that can be tapped by *researchers and analysts* seeking to develop additional

improvements and innovations. Data on driver behavior will be of interest to both traffic operations and safety researchers. The SHRP 2 project on future concepts of operations will undoubtedly generate many innovative ideas on how to achieve future goals. Data and information tend to provide adequate incentive for researchers and analysts; they generally need little encouragement to analyze data. However, access to the data could pose a barrier. The archive of Reliability data must be retained in an easily usable format. Some data sets may include proprietary data or private information concerning individual citizens that may require special safeguards against inappropriate use.

CONCLUSION

Congestion is a difficult and complex problem. A realistic and effective way to address the problem is to better manage the incidents that produce nonrecurring congestion and mitigate the associated impacts. These incidents, which include crashes, work zones, special events, and inclement weather, can increase congestion significantly and unexpectedly. Reducing this unpredictability is the focus of SHRP 2 research on travel time reliability. The benefits of this research, if it is effectively implemented, include an overall decrease in congestion; increased safety for motorists and incident responders; and savings of time, money, and fuel emissions. These benefits will prove of significant value to society and the nation's economy, but only if sufficient resources for implementation are made available.

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
BLS	Bureau of Labor Statistics
TTI	Texas Transportation Institute
WSDOT	Washington State Department of Transportation

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5 Capacity Focus Area

SHRP 2 Capacity program goal: To develop approaches and tools for systematically integrating environmental, economic, and community requirements into the analysis, planning, and design of new highway capacity.

Growth in automobile and truck vehicle miles traveled has consumed much of the road capacity constructed during the Interstate era; major forces described in Chapter 1 are at work in some areas of the country demanding more transportation capacity. Much of this capacity will be provided by highways, even with aggressive transit investment and more aggressive management of existing highways through value pricing, improved traveler information, in-vehicle telematics, removal of bottlenecks, and ramp metering. Creating new highway capacity will have significant environmental and social impacts. Without changes, additional travel will exacerbate the nation's oil importation problems, increase greenhouse gas emissions, affect wildlife habitats, and disrupt communities. The public will insist on a convincing environmental, economic, and social justification for the investment required to expand highways—including demonstration that all of the capacity possible has been obtained from existing highways and arterial streets—and on a heightened level of environmental stewardship by highway agencies.

SHRP 2 CAPACITY RESEARCH

SHRP 2 Capacity research projects address the above challenges. Support from many players is required to build a new highway or complete a major capacity expansion. Collaborative decision making is essential

to success, supported by an effective strategy for enhancing the environment, improving economic vitality, and achieving social goals (see Box 5-1). Also needed are tools for estimating the outcomes of decisions and communicating those expected outcomes to the public and decision makers. Implementation of the results of these efforts will require commitment to change by the nation's departments of transportation

Box 5-1

GRAND RAPIDS, MICHIGAN, US-131 S-CURVE REPLACEMENT

This project is an example of a collaborative decision-making process in which the Michigan Department of Transportation (MDOT), the Grand Valley Metro Council (a metropolitan planning organization), the chamber of commerce, local Indian tribes, adjacent property owners, and commuters formed a partnership for compromise and success.

In 1998 MDOT discovered that a pier supporting a downtown bridge was sinking. An "as is" replacement strategy was not acceptable to the community; many preferred to have the S-curved bridge straightened for safety and capacity reasons. This solution was not feasible because of cost and right-of-way constraints. MDOT proposed a widened, safer, and more aesthetically pleasing S-curve structure, with demolition and reconstruction being accomplished in one season. Businesses and the public compromised on the design but felt that the one-season plan was tantamount to closing the downtown area. MDOT initiated an extensive and transparent community involvement program, developed an aesthetic look for the bridge, identified detour routes early on, and responded carefully to comments and questions. MDOT fit the new structure into the original right-of-way; an environmental assessment revealed that this approach would allow the project to avoid a lengthy environmental impact analysis, an estimated 7-year process. Extensive archeological and historic preservation issues still arose, but they were addressed successfully in the environmental assessment.

Through collaboration on the design concept, aesthetic appeal, environmental strategy, and construction schedule, a wider, safer, and more pleasing structure was built with the available budget. Within 33 months of the detection of a sinking bridge pier, a new bridge was opened to traffic. The project won the National Quality Initiative Bronze Award for partnering in 2000.

SOURCE: Grand Rapids, Michigan, US-131 S-Curve Bridge Replacement (case study prepared for SHRP 2 Project C01 by ICF International, 2008).

(DOTs), metropolitan planning organizations, zoning authorities, and resource agencies.

The SHRP 2 Capacity focus area comprises projects in four theme areas: (*a*) elements of collaborative decision making, (*b*) an ecological approach to surface environmental protection, (*c*) improved tools for analysis of travel behavior, and (*d*) tools for estimating the economic impacts of highway investment. These four theme areas are the basis for strategic packaging of the results of multiple research projects. The first theme area encompasses the central product of SHRP 2 Capacity research: the Collaborative Decision-Making Framework (CDMF). The other three theme areas address particular types of tools or data that support the CDMF but also may be used as independent products. A list of projects in the Capacity focus area and corresponding products is provided in Appendix B.

PROMISING PRODUCTS, AND POTENTIAL USERS, INCENTIVES, AND BARRIERS

The results of individual Capacity projects will have their own benefits for those interested in those particular topics. However, the end product of Capacity research will be nothing short of systematic integration around key decision points of practice whose value has been demonstrated in applications over the past 15 to 20 years: providing for interactive public involvement and for consultation among affected agencies; incorporating more environmental work into planning and successfully navigating the National Environmental Policy Act (NEPA) and permitting processes; introducing an environmental stewardship culture into transportation agencies; embracing an ecological approach to the environment; seriously looking at improved highway efficiency through operations, telematics, and pricing; communicating the economic benefits of highways in a more compelling and transparent way; and dealing with public–private partnerships. Accomplishing this amounts to rewriting the book on transportation planning to reflect collaborative decision-making principles. The final product will be an integrated, web-based product organized on the basis of key decision points in the process for delivering new highway capacity.

Collaborative Decision-Making Framework[1]

The essence of the CDMF is having the right people at the table at the right time with the right information (see Box 5-2). Achieving this requires continual attention because the transportation decision-making process comprises many individual steps. Key decisions are those points in the process where the general work activities need review and approval from higher levels of authority or where consensus needs to be reached among diverse decision makers before the project can advance. For this reason, key decisions most often occur in the policy decision-making process. Key decision points, therefore, represent only a portion of the overall decision-making

Box 5-2

THE SAN ANTONIO KELLY PARKWAY

An 8.8-mile, four-lane, limited-access parkway was proposed in southwest San Antonio to spur economic redevelopment of the former Kelly Air Force Base by providing access to an inland port and improving linkage of the former base to the regional highway network. Community leaders saw the project as a redevelopment opportunity that would relieve truck congestion and bring economic opportunities to the low-income south side of the city. However, organized opposition developed in the largely Hispanic neighborhoods along the route. The project team worked with the community to select a parkway-style limited-access road that would use the alignments of existing roads and railroads to minimize community impacts.

More than 100 stakeholder meetings were held. Issues addressed included environmental justice, safety, transportation of hazardous materials, and concern that construction would release groundwater contaminants known to be on the base. A breakthrough occurred when a long-standing faith-based community organization became supportive because the problems could be fixed and the economic benefits, improved connectivity, and beautification opportunities were great.

A record of decision was signed in 2006. Although the project is currently on hold pending funding, it represents an example of integrated planning, creative use of existing rights-of-way, economic redevelopment, and proactive community involvement.

SOURCE: The San Antonio Kelly Parkway (case study prepared for SHRP 2 Project C01 by ICF International, 2008).

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[1] This description of the CDMF is adapted from material provided by SHRP 2 Capacity contractor ICF International.

process, but these points effectively link existing planning and project development processes and practices. Many key decision points are common among transportation agencies. Some are defined by law, while others have arisen through convention or through adoption of good practices. Because state laws and regulations vary, the individual work activities that link and feed key decision points can be different from state to state.

SHRP 2 is developing the CDMF to identify key decision points in four phases of transportation decision-making processes:

1. Long-range transportation planning,
2. Corridor planning,
3. Programming, and
4. Environmental review and permitting.

The CDMF incorporates overall context-sensitive solution (CSS[2]) and project management principles and is built on a set of design goals established by SHRP 2. The design goals provide the following guidance:

• Establish a collaborative decision-making approach that identifies participant roles and responsibilities at each key decision point and includes (*a*) early and ongoing involvement of formal decision makers and individuals with the potential to significantly affect the timely and cost-effective delivery of transportation improvements and (*b*) a tiered decision-making approach to capacity improvements that encourages binding decisions at the earliest possible point.

• Encourage timely and cost-effective project delivery through a process that (*a*) ensures transfer of information and decisions between phases; (*b*) encourages early and comprehensive agreement on data sources, level of detail, evaluation criteria, and performance measures; and (*c*) establishes a comprehensive and proactive risk management strategy.

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[2] The Center for Environmental Excellence of the American Association of State Highway and Transportation Officials defines CSS as follows: "Context sensitive solutions is an approach to advancing transportation programs and projects in a collaborative manner and in a way that fits into the community and environment....[T]he concepts of CSS [go] well beyond the design process to include all phases of program delivery, including long-range planning, programming, environmental studies, design, right-of-way, construction, operations, and maintenance." http://environment.transportation.org/environmental_issues/context_sens_sol/ #bookmarksubWhatisCSS.

• Encourage a decision-making approach that evaluates transportation needs within broader community and environmental contexts; integrates land use planning and development policy, capital improvement planning, and protection and enhancement of the human and natural environments; and addresses sustainability issues to the extent possible so as to support community vision and goals.

• Encourage consideration of a wide range of options for addressing capacity problems during the planning phase of decision making, as well as early and ongoing incorporation of operational elements as a part of the overall decision-making approach.

• Establish a decision-making approach based on fulfilling the intent of legal and regulatory requirements while providing implementation flexibility and adaptability consistent with the design goals.

The CDMF is intended to be readily available to all practitioners who wish to implement a collaborative decision-making approach, whether throughout the entire transportation decision-making process or only in specific areas. For this reason, the ultimate vision is for the framework to be accessed through a web-based tool. The architecture of the CDMF is being designed with this vision in mind. The structure of the CDMF encompasses a series of portals through which increasingly detailed information can be retrieved for each key decision point, first at the entry level and then at the practitioner level.

Figure 5-1 is a schematic of the CDMF entry level, illustrating how a user can access information through a series of portals where one or more key decision points occur. The figure illustrates the upper-level steps in decision making, as well as how the individual phases relate to one another. A design goal listed above is "timely and cost-effective project delivery." One of the choices a user of the framework will need to make is which steps to conduct in parallel rather than in sequence and what risks are entailed. The web-based product is being designed to help practitioners select a strategy for a particular capacity enhancement that will avoid redo loops, successfully hand decisions forward in the process, establish an interactive link between planning and project development, engage the community at the right time, and ensure that the transportation decision-making process includes the larger goals and visions of the region. The intent of the CDMF

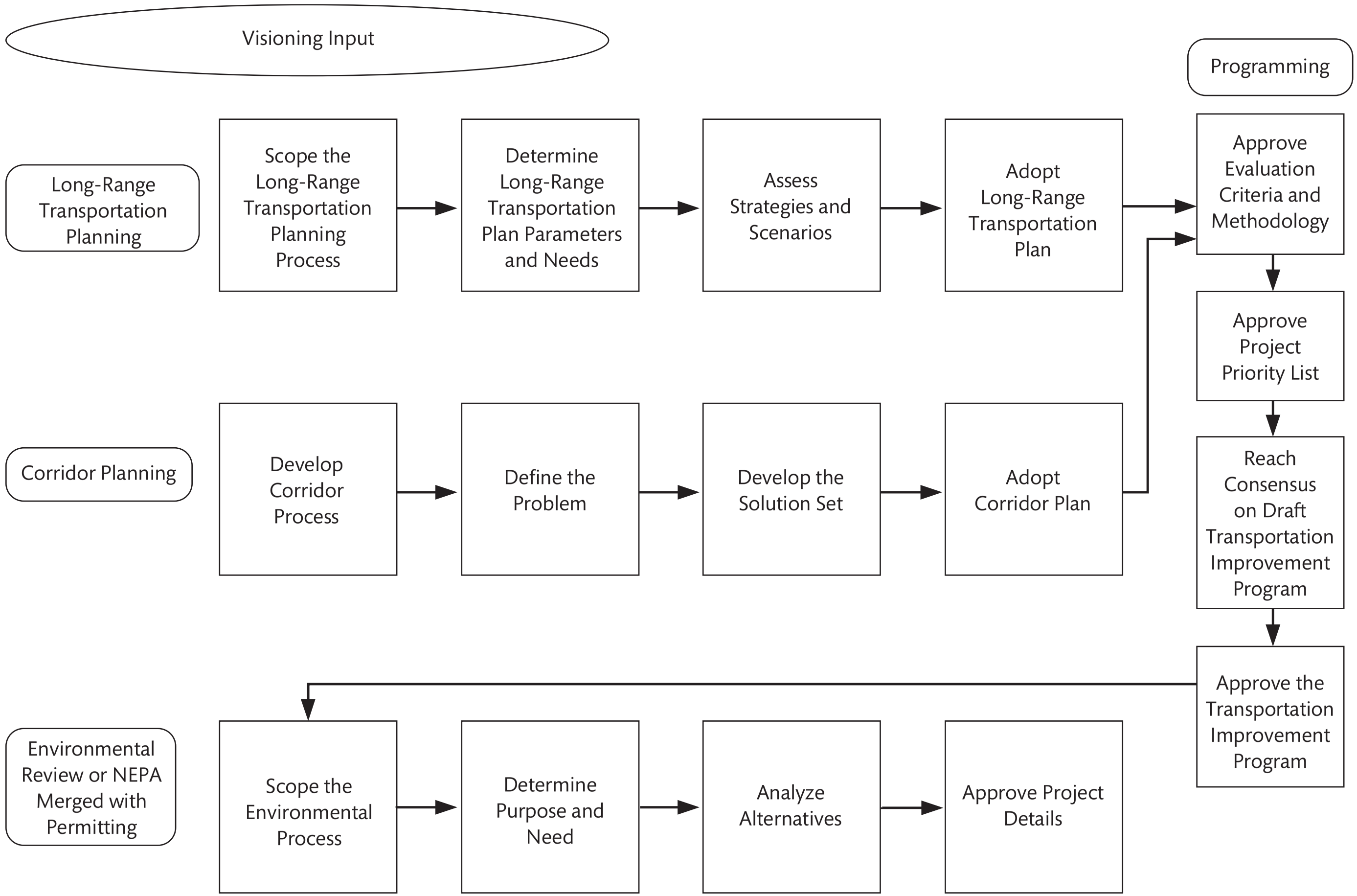

FIGURE 5-1 CDMF ENTRY LEVEL.
Source: SHRP 2 Project C01, work in progress.

is to help practitioners determine the best transportation solution by engaging the community effectively and ensuring environmental stewardship. The community visioning process illustrated in Figure 5-1 is recommended as a best practice to ensure that the transportation decision-making process reflects the larger goals and visions of the region.

Although Figure 5-1 provides a concise overview of the CDMF, transportation practitioners will need specific information at each key decision point to consider implementation of the collaborative decision-making process. A CDMF practitioner-level version will provide access to the full extent of information available at each key decision point, including the following:

- The purpose and outcome of the key decision point;
- Decisions made at each step;
- Roles and responsibilities of the formal decision makers;
- Roles and relationships of stakeholders and project champions;
- Supportive data, tools, and technology;
- Related influential processes and subprocesses;
- Primary products of this step;
- Associated best practices; and
- Linkage to other SHRP 2 Capacity research, such as the Performance Measurement Framework and case studies on economic impacts of transportation investments.

Other community and environmental planning processes are external to but have an impact on transportation decision making. Examples are economic development plans, wildlife action plans, watershed plans, open space and recreation plans, land use plans, air quality plans, and greenhouse gas initiatives. Within the CDMF, these processes are identified as subprocesses or influencing processes. While subprocesses have a direct effect on transportation decision making through certain critical-path steps, other external processes, such as the development of wildlife or watershed action plans, strongly influence transportation decision making; best-practice collaboration would engage these processes as well.

The integrated web-based tool that represents the ultimate vision for use of the CDMF will allow users to enter the framework at any point and follow a topic of interest through all the available information. Results of

individual SHRP 2 Capacity research projects will be synthesized and condensed in a final user-oriented product with links to full-text source material supported by examples and illustrations. This is essentially a new collaborative planning tool focused on decisions, not process.

Implementing the CDMF will require a number of elements. A case for change must be made; that is, state DOTs and metropolitan planning organizations must recognize that there are problems with the current way in which highways are delivered with respect to the public acceptability of design solutions, excessive delays, and difficulty in achieving consensus and support on community and environmental issues. Highway-owning agencies will need to adopt a risk management philosophy that considers it wise to invest in building consensus up front so as to be more efficient downstream by avoiding rework, revisiting of alternatives previously dismissed, and other delays. Agency champions must come forward to demonstrate the benefits of doing business in the new way. Representatives of highway and environmental resource agencies must be involved in designing the research products that address problems. A brand name may need to be developed for the CDMF. And last, but definitely not least, an entity must be identified and funded to own, maintain, and update the tools that form the CDMF in much the same way that the *Highway Capacity Manual* and the American Association of State Highway and Transportation Officials' *Policy on Geometric Design* have ownership structures and updating mechanisms.

Incentives to implement the CDMF stem from its two principal benefits. First, it promises to produce better decisions on transportation projects by bringing the right people and information together at the right time and by preserving decisions and reasoning from one stage to the next. Second, decisions are likely to be made more quickly because of this integrated approach, which promotes smoother and more timely flow of information and reduces the need to revisit earlier stages. The CDMF can be expected to have the additional benefit of improving a transportation agency's relationships with its partners and stakeholders by promoting more transparent communication and decision making.

A number of barriers to implementation of the CDMF can be anticipated. First, the CDMF could be perceived as a one-size-fits-all solution. It must be emphasized that the CDMF is a framework, not a specific process. Any user who agrees with the framework's essential approach—collaborative

decision making that integrates social, economic, environmental, and technical considerations—can use as much or as little of the CDMF as desired. The framework is designed to address all legal requirements and to be compatible with established processes in different agencies.

There are also costs associated with implementing the CDMF in states and metropolitan planning organizations. More staff time may have to be devoted to public engagement and early strategizing with resource agencies. This is really the cost of a risk management strategy: spending more up front to build consensus makes it possible to avoid much greater costs downstream associated with delay and rework.

Another potential barrier to implementing the CDMF is insufficient data in some jurisdictions. The CDMF is predicated on having the right information at each stage; if the information is not available, the effectiveness of the framework may be compromised, at least in particular jurisdictions or for specific key decision points. An agency can use parts of the CDMF for which it has the appropriate data and expand its use of the framework as it acquires additional data.

Ecological Approach to Surface Environmental Protection

The Federal Highway Administration (FHWA) document *Eco-Logical* provides the conceptual foundation for the projects in this group. *Eco-Logical* recommends integrated conservation plans and mitigation activities that transcend individual agency jurisdictional boundaries and encourages an outcome-based ecosystem approach to conservation. *Eco-Logical* was signed by FHWA and eight other federal agencies with environmental responsibilities that are on the critical path to expansion of highway capacity. As such, it provides an excellent springboard for developing an ecological approach to conservation and mitigation that should help in achieving public consensus as part of the collaborative decision-making process. Box 5-3 provides an example of such an ecological approach.

The products of the SHRP 2 projects in this area will be an ecosystem-based credits system, business model, and guidelines designed to enable conservation banking or other strategies to rise above resource-by-resource mitigation. The research plan envisions the use of a multiagency advisory body to guide the work and build support. This work may form the basis for future revision of regulations pertaining to wetlands and habitats. The

Box 5-3

CALIFORNIA MULTIPLE PROJECT CONSERVATION FOR SPECIES OF CONCERN

This project is one of many examples of success reported in *Eco-Logical:*

> FHWA, California Department of Transportation (Caltrans), and several local transportation agencies are planning five interchange improvements on Interstate 10. These improvements will impact sand dune habitat that houses two listed species of concern: the Coachella Valley fringe-toed lizard and milk vetch. Rather than develop discrete conservation measures for each project, the participating agencies have developed a mitigation strategy for the five interchange projects that will be carried out as each project goes through the environmental process. As a result, the U.S. Fish and Wildlife Service will issue a Programmatic Biological Opinion for the five interchange projects, which will expedite project delivery. Participating agencies are preparing a draft cooperative agreement and will begin acquiring land from willing sellers as soon as each project completes its environmental document. Approximately 1,800 acres will be conserved for the five projects. (Brown 2006, 53)

This project is an example of considering the ecology of a large region to protect the habitat for at least two species of concern. The interchange construction projects were expedited, and the sensitive land was protected in perpetuity.

intent is to develop a scientifically sound system of credits or programmatic strategies that can provide a means to implement a multiagency ecological approach for protecting and conserving the environment.

Despite the interagency consensus reflected in *Eco-Logical,* current practices and procedures developed in response to regulations and laws dictate that resources be considered individually. To put the ecological approach into practice, it will be necessary to develop scientifically sound solutions to the following issues, which are addressed in SHRP 2 research:

- Defining environmental functions and quality of wetlands and assigning credit values;
- Defining environmental functions and quality of habitats and assigning credit values;

• Designating service areas that are sufficiently flexible so that critical mass habitats and ecosystems can be developed, preserved, or enhanced; and
• Developing a method to demonstrate that the ecosystem approach and credits satisfy the various statutes and regulations that apply.

The main incentive behind the projects in the ecological theme area is to preserve and improve the natural environment in the process of providing new highway capacity. The products of this research can be used on their own, but their benefits are most apparent in the context of the CDMF. Specific products include methods and procedures for interagency environmental cooperation and science-based approaches to habitats, wetlands, and endangered species—the kinds of tools that support collaborative decision making around key decision points pertaining to environmental protection.

There are several conditions for successful implementation of the ecological approach:

• Awareness among regulatory agencies of acceptable regulatory interpretations. A narrow interpretation of a regulation may preclude a beneficial ecological practice.
• Willingness of transportation agencies to embrace a broader role in environmental stewardship. This requires developing a business case for doing more than is strictly required by regulation.
• Willingness of affected agencies to pursue changes to accepted practices that may be needed to implement an ecological approach.

To fully attain the benefits of research in this theme area, it will be necessary to overcome any potential perception on the part of environmentally interested parties that SHRP 2 tools will adversely influence hard-won regulations addressing wetlands and endangered species. This can be accomplished by ensuring that consensus exists on the underlying science that supports the research products. In addition, road owners will have to demonstrate a commitment to multipurpose conservation and avoidance of sensitive environmental areas. It will probably be necessary to show that the environment is not only unharmed but actually better off with the highway than without it.

Another barrier to implementation of the ecological approach is the large number of agencies involved. Systematic attempts to engage all these stakeholders have begun in the research phase of SHRP 2 and must be carried on throughout implementation. As in the other areas of Capacity research, a lack of data can also hinder an agency's ability to fully utilize some of the ecological tools produced.

Improved Tools for Analysis of Travel Behavior

Current travel demand models and static networks are inherently incapable of analyzing the questions being asked today about traveler responses to tolls and congestion, the behavioral impacts of travel time variability, the relationship between transportation and land use, and the air quality and greenhouse gas consequences of capacity-enhancing transportation proposals (TRB 2007; see Box 5-4).[3] To address these issues, FHWA and about 10 states and metropolitan planning organizations have invested in the new generation of activity-based travel demand models; both FHWA and private entities have developed time-sensitive network software. However, no one has successfully integrated advanced models and time-sensitive networks and demonstrated that they can actually perform as intended. The result is hesitancy to move forward. SHRP 2 will act as a catalyst to advance the state of modeling practice by partnering with one or two agencies already using advanced models. SHRP 2 will provide additional support to assist these agencies in completing a model set, using some SHRP 2 products, and in conducting prespecified sensitivity tests. The nominal product of this effort will be reports describing the methods and the degree to which the sensitivity tests demonstrate the value of this approach. The most valuable outcome will be demonstration of success to states and metropolitan planning organizations so they perceive less risk and can adopt the new methods with confidence.

[3] *Special Report 288: Metropolitan Travel Forecasting: Current Practice and Future Direction* (TRB 2007) recommends federal funding to support the adoption of advanced models by transportation forecasting agencies, a national travel forecasting handbook, a supportive research program, a peer review structure, model user groups, and studies of the efficacy of advanced models. SHRP 2 is conducting research that will advance the recommendations of *Special Report 288* by examining the efficacy of advanced models and time-sensitive networks with respect to congestion, shift in time of travel, shift in route, response to tolls, response to smart-growth policies, and inputs from evaluation of greenhouse gas emissions. Other recommendations in *Special Report 288* have been considered in proposing an implementation approach for the products of this theme area.

Box 5-4

ASSESSMENT OF TRANSPORTATION PLANNING MODELS

Special Report 288: Metropolitan Travel Forecasting: Current Practice and Future Direction, released by the National Research Council, describes the reasons why a strategic approach to capacity enhancement must address travel demand models and networks. Critiques of the ability of the current modeling process to address the issues with which metropolitan planning organizations must deal are numerous. On the demand side, the process is not behavioral; that is, it is not well suited to representing travelers' responses to the complex range of policies typically of interest to today's planners. On the supply side, the process cannot represent dynamic road conditions. The following are among the issues that the current, widely used metropolitan demand forecasting process cannot adequately characterize (TRB 2007, 67):

- Road pricing, including high-occupancy toll lanes;
- Time-specific policies, such as parking, work schedules, or scheduling of truck deliveries;
- Hourly speeds or traffic volumes;
- Improvements in traffic operations;
- Nonmotorized travel;
- Peak spreading and highly congested networks; and
- Goods movement.

Taking full advantage of new and existing road space requires the ability to analyze these aspects of highway capacity alternatives.

SHRP 2 projects in this theme area are also developing the mathematical relationships among motorist behavior, pricing, and congestion. The results of this work are intended for use in travel demand models. Another project will demonstrate the effects of highway management strategies on sustainable highway throughput in peak conditions. These results will be applied in a modeling and operations environment.

The ability to obtain answers to these difficult planning questions is the main incentive for using these SHRP 2 products. However, a number of potential barriers to implementation of these products exist. Implementation of a new generation of transportation models and time-sensitive networks will require investments in software, updated travel surveys, and staff.

The first challenge is communicating the results of SHRP 2 research and field demonstrations to the many organizations involved in transportation planning at the state, regional, and local levels. Numerous dissemination structures exist. The Transportation Research Board (TRB) has at least six standing committees concerned with travel analysis methods, as well as a task force on implementing advanced models; an ad hoc group of stakeholders exists for the same purpose. The Association of Metropolitan Planning Organizations has a committee on travel demand modeling. The effectiveness of communication efforts will depend on translating the results of SHRP 2 demonstration projects into actionable items for each city and state.

The perception exists that advanced models and networks are needed only by large urban areas or states. However, almost all areas are being forced to rely less on construction and more on management of highways, which requires advanced techniques. Unfortunately, there is a limited pool of expertise in advanced models and networks, and successful implementation will require widespread development of such expertise. The lack of trained staff and funds to collect the data needed to support the advanced models is a significant barrier to implementation.

Economic Impacts of Highway Investments

This theme area addresses analysis of the economic impacts of highway capacity expansion. While techniques and software tools for this task abound, a lack of transparency makes it difficult to communicate results to decision makers and the public (Box 5-5 provides an example of these challenges). One project in this theme area will conduct before-and-after case studies built on a typology of conditions that includes type of highway, location on an urban–rural scale, and type of area (e.g., growing sunbelt city). The case study background will include unique conditions that may be associated with an impact, such as industrial development policies or tax incentives. A practitioner's handbook will be developed that will make development impacts more transparent to noneconomists and provide the basis for approximation of impacts by analogy. A second research project will develop improved economic analysis tools and integrate these tools with the case-based reasoning tools produced by the case study research.

Implementation of the results of research in this theme area will benefit from coordination with a number of existing organizations and groups. For

Box 5-5

USING CASE STUDIES AND META-ANALYSIS TO INFORM THE PUBLIC AND DECISION MAKERS

The California Department of Transportation (Caltrans) was planning a number of new highway bypasses to relieve congestion in local communities. However, agency planners understood that these types of projects are often controversial, with some civic leaders supporting them and local business leaders expressing concern about loss of sales. In the past, a lack of information often had led to unrealistic fears and expectations. To address this problem, Caltrans staff sponsored a study to improve basic knowledge about the impacts of bypasses on the economic health of small towns. The study compiled state and national information covering more than 200 built bypass projects to assess actual before-and-after experiences and factors affecting those outcomes. The project team then developed a spreadsheet tool—the Highway Bypass Impact model—that applies this information to help forecast potential economic impacts of planned future bypasses. Caltrans staff will be using the study findings and analysis tool to enhance the ability of local residents and officials to make judgments about likely impacts of proposed projects on their communities.

Source: System Metrics Group et al. 2006.

example, TRB has a Committee on Transportation and Economic Development. The National Association of Regional Councils is also active in this area, and there are associations explicitly devoted to economic development professionals. Most states and cities have an economic development group, but they do not necessarily communicate regularly with transportation planners and engineers. There is fertile ground here for communication and outreach. Implementation mechanisms may emerge from the case study research since it will involve 50 or more cases. TRB's Committee on Transportation and Economic Development, in conjunction with FHWA and others, sponsors a major research conference every few years. One of these conferences may be an appropriate opportunity to showcase the results of SHRP 2 work in this area.

The greatest barrier to implementing products of research in this theme area is the inherent complexity of the topic and the lack of transparency of traditional tools. The data-based, econometric approach yields answers,

but decision makers and the public are not sure how much confidence they can have in those answers. A second barrier is the sheer number of special-purpose analytical products now available. In effect, data are run through a chain of black boxes to yield an answer. The SHRP 2 products will be introduced into this environment, adding a case-based approach to the various existing analytical approaches. Extra effort will be necessary to demonstrate the reasonableness and transparency of the SHRP 2 tools.

CONCLUSION

SHRP 2 Capacity research represents a bold effort to reimagine the way highway projects are planned and prepared for and to provide innovative tools that support the new approach embodied in the CDMF. Achieving the objectives of this research is critical to meeting mobility needs in the 21st century in a socially and environmentally responsive manner. The barriers to successful implementation are not trivial, but it is difficult to imagine how highway capacity can be provided effectively without adherence to a framework such as that described here. The availability of sufficient resources to integrate this framework into capacity planning at all levels will be critical to its successful implementation.

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Abbreviation

TRB Transportation Research Board

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6 Implementation of SHRP 2

Principles and Key Strategies

This chapter articulates principles and key strategies for the implementation of SHRP 2 research products that serve as the foundation for the implementation approach presented in Chapter 7. The chapter begins by reviewing challenges and opportunities that serve as the context for the implementation of innovations in the highway industry. This is followed by a look at lessons learned from implementation of the first SHRP. These lessons inform the ensuing discussion of principles and strategies for SHRP 2 implementation.

INNOVATION IN THE HIGHWAY INDUSTRY: CHALLENGES AND OPPORTUNITIES

Innovation in the highway industry has been a subject of some interest over the past two decades (Bernstein and Lemer 1996; Bikson et al. 1996; Byrd 1989; Civil Engineering Research Foundation n.d.; Gittings and Bagby 1998; Hodgkins 1989; Scott 1999; TRB 1994; TRB 1996; TRB 1999). The spread of innovations in the industry is characterized by a number of challenges and opportunities that must be understood in the context of the public policy decisions and trade-offs that characterize public infrastructure. Highways and roads are usually under the stewardship of the public sector, which owns and often operates them. However, the private sector has always played a significant role as designers, builders, manufacturers, suppliers, and providers of financial services; it is also playing an increasing role in operating the system through toll roads and high-occupancy toll lanes.

The traditional system of providing highway infrastructure emerged in response to several public policy goals: (*a*) to provide the infrastructure as

widely as possible, (*b*) to do so at a reasonable cost, (*c*) to apportion this cost in an equitable manner, (*d*) to allow for broad participation by the private sector in competing for highway contracts, (*e*) to ensure that qualified contractors win the jobs, and (*f*) to ensure that the price paid for their services is both fair to the contractors and a responsible use of public funds. This context helps explain some of the challenges to innovation in the highway industry:

- *The decentralized nature of the industry:* Fifty states and thousands of local governments own and operate highways, each having its own procurement regulations, specifications, organizational structure, and specific scope of responsibility. There are also thousands of private firms of all sizes, from local to international, that provide products and services to these government entities. This characteristic of the industry slows widespread implementation. While efforts to centralize product testing and evaluation facilitate the use of innovations, they do not guarantee that individual state and local agencies will accept the results or use the products.
- *The low-bid system:* The practice of awarding highway contracts to the lowest qualified bidder tends to leave little room for a contractor to introduce innovation. If an innovation costs more, the contractor will not win the bid even if improved performance justifies the greater cost. Innovative procurement approaches are being used, but they raise issues of risk allocation, impact on the competitive position of some traditional or smaller firms, and potential misunderstanding by the public when contractors receive nontraditional payments (such as incentive payments) under such innovative schemes.
- *Materials and methods specifications:* Typically, the low-bid system utilizes materials and methods specifications. These prescriptive specifications ensure that all bids are for the same end product and provide a basis for determining whether that product has been delivered. If an innovation fails to follow the specifications precisely, it is not allowed. A way to overcome this difficulty is to develop and use performance specifications that indicate the performance desired instead of prescribing the technologies to be used. However, it has been challenging to establish measures of performance for complex, long-lived facilities.
- *First-cost criterion:* Traditionally, agencies have focused on the “first cost” or construction cost of a facility in determining the low bidder. This

focus excludes the use of any technology that increases the first cost even if it reduces the cost of maintaining and using the facility over its lifetime or reduces the user and social costs of the infrastructure. Attempts have been made to use life-cycle costs in comparing technologies, but such attempts have raised questions about how to calculate these costs. (Should user costs be included or just agency costs? How should the time value of money be treated?) Another difficulty is more political in nature. If the amount of money available for highway work is fixed for a given year, funding projects with higher first costs means not initiating as many projects—or satisfying as many constituents—in that year.

• *Prohibition of proprietary products:* A related aspect of the procurement process is that proprietary products usually are not allowed because they limit competition and fail to conform to materials and methods specifications. There are usually some exceptions to rules against proprietary products, but these exceptions ordinarily allow the product to be used only once or in a limited number of cases. In addition, public agencies are often concerned about product liability when they use (or allow their contractors to use) a proprietary product or one that does not adhere to clear standards, guidelines, or approvals from national entities such as the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), or the American Society for Testing and Materials (ASTM).

• *Risk management:* Risk is inherent in trying anything new; some technological and methodological innovations can cause risk to be reallocated among stakeholders in a project. For instance, some innovative procurement procedures (such as warranties and use of performance specifications) shift control over, and therefore responsibility for, product quality from the transportation agency to the contractor. Unwillingness or inability to accept increased risk can be an impediment to implementing an innovative approach. Because of their responsibility to the public and the incentive structure they face, highway agencies tend to be risk averse. At both the individual and agency levels, there is little reward for success in innovation, and there are potentially huge penalties for failure.

• *Vested interests:* In some geographic areas and some product categories, particular industries or firms exert significant political influence over agencies' technology choices, so that even a willingness to innovate will

be thwarted by pressure to use technologies offered by politically favored industries or firms.

- *Staffing challenges:* Transportation agencies nationwide have been experiencing staff reductions in recent years due to both political pressures to reduce the size of government and the retirement of the large cohort of employees hired to plan, design, and build the Interstate highway system. Decades of experience and expertise are being lost with these employees, who could have helped identify and implement the most effective innovations. At the same time, many agencies find it difficult to attract, train, or retain the expertise required to implement some new technologies because of salary differentials with the private sector, downsizing of public agencies, and outsourcing (TRB 2003). The combination of outsourcing of technical work, downsizing, and retirement of skilled workers and management can leave highway agencies lacking the experience and skills needed to recognize, accept, and promote new ideas and innovations.
- *Data challenges:* The value of many new technologies is dependent on the availability of data in a wide range of areas, including planning, highway operations, asset management, environmental assets, agency and user costs, and safety. Transportation agencies often lack the data they need and cannot afford to collect, maintain, and update those data. In some cases, the data they have are partial, outdated, or incompatible with each other and with new management systems. When the data can be collected or purchased from the private sector, cost and privacy issues can be obstacles.

At the same time, the highway industry has a number of favorable characteristics from the point of view of innovation. Most of these characteristics mitigate the highly decentralized nature of the community by facilitating the common pursuit of research and development (R&D) and providing mechanisms for information dissemination and learning:

- *Federal–state partnership:* For more than a century, FHWA (and its predecessor agency, the Bureau of Public Roads) has worked closely with highway agencies in the 50 states, the District of Columbia, and Puerto Rico. The federal agency's ability to attract national expertise and support a wide variety of research, development, and technology transfer activities has provided a source of new ideas and support for their implementation

that are beyond the reach of many individual state agencies. The promulgation of uniform standards for the Interstate highway system raised the level of highway quality for many jurisdictions.

• *State–state partnerships:* While each state has its unique needs, groups of states often pool funds to perform research that meets common needs. Some of these pooled-fund studies focus on research of interest to a specific region or subset of states and may leverage private and academic resources as well. FHWA supports pooled-fund arrangements by facilitating administration of the funding or by contributing additional funds. The National Cooperative Highway Research Program, established in 1962 and administered by the Transportation Research Board (TRB), carries out collective R&D activities under an arrangement that pools funds from all the state departments of transportation (DOTs). AASHTO also provides opportunities for states to leverage their technology investments. For example, through the AASHTOWare program, states can pool funds to develop and support software packages they would otherwise have to support individually at much greater cost. AASHTO also promotes peer exchanges between states and coordinates the development of consensus standards and manuals, such as the *Policy on Geometric Design of Highways and Streets* (the Green Book).

• *University transportation programs:* A network of programs across the country—some of which participate in the University Transportation Centers Program—supports basic and applied research yielding new knowledge of highway-related materials, technologies, methods, relationships, and behavior and prepares future transportation professionals. Many state DOTs have a close relationship with the universities in their states. University-based programs often provide a vehicle for broader collaboration with the private sector and local governments.

• *TRB:* A unique national collaboration exists through TRB in which professionals from federal and state agencies, universities, and private firms work together to identify research needs, disseminate information, sponsor conferences and workshops, and carry out other activities that promote innovation in the transportation sector.

• *Special-purpose strategic programs:* The highway industry has supported a number of special research and technology programs, including the American Association of State Highway Officials Road Test, the first SHRP, SHRP 2, and the Intelligent Transportation Systems Program, as specific needs or new opportunities have arisen.

• *Training and technology transfer programs:* Federally funded programs, often matched by state funds, provide technology transfer and training to local governments and Native American tribes so that innovations developed at the federal and state levels can be disseminated to these local entities, which typically have little or no money to conduct their own R&D.

LESSONS LEARNED FROM THE ORIGINAL SHRP

Two of the better known and more widely implemented results of the first SHRP are the Superpave® system for designing asphalt pavements and a collection of methods and technologies that significantly improved snow and ice control on roadways. By 2005, a little more than a decade after the research phase of SHRP 1 had ended, nearly all U.S. state DOTs, as well as several Canadian DOTs and other U.S. agencies, had implemented Superpave to some degree (see Figure 6-1), a remarkable penetration of innovation for this industry. This degree of implementation was projected in 1997 to provide $22.5 billion in savings for public agencies and highway users combined (FHWA 1997a). Half this level of market penetration for SHRP 1 snow and ice control products was projected to save $55 billion per year for agencies, not including improved safety and mobility for highway users (FHWA 1997b).

Activities that supported the implementation of these and other SHRP 1 research products were administered by FHWA with funds authorized in the Intermodal Surface Transportation Efficiency Act of 1991. During the time that specific funds were authorized for SHRP 1 implementation, FHWA played the lead role in overseeing, coordinating, encouraging, and facilitating widespread deployment of SHRP 1 results. The SHRP 1 implementation experience provides many examples and lessons that could be useful in planning the implementation phase for SHRP 2. These are categorized below under research products, implementation agents, implementation mechanisms, and resources.

Lessons Learned from SHRP 1 Concerning Research Products

Recognize That Research "Findings" Are Not "Products"

Research results must be translated into products that a user wants to implement. This translation requires a constant revisualization of the product; researchers are often not good at this step, so it is critical that users be

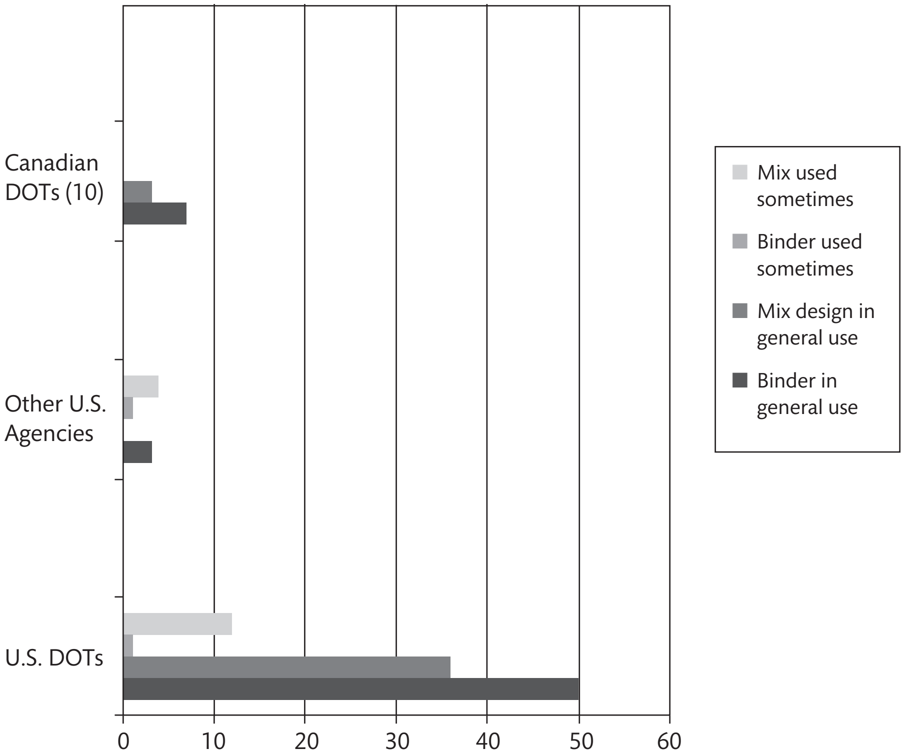

FIGURE 6-1 SUPERPAVE DEPLOYMENT IN NORTH AMERICA, 2005.
Source: TRB 2005.

engaged early and often in the process. A research result will sometimes require additional adaptive research and often further development before a usable product is ready for implementation. Recognition of this possibility is important both for planning and budgeting and for managing the expectations of users, who may believe that the research program has addressed issues that may not arise until real-world trials are attempted.

Recognize That SHRP Products Are Different

In both the first SHRP and SHRP 2, the objective has been to create "step function" rather than incremental or continuous improvement. This means that successful implementation of SHRP 2 results may be disruptive to existing states of practice: users will be required to think differ-

ently, act differently, and possibly organize their institutions differently. It is critical that potential users understand this up front and be persuaded that improvements derived from SHRP 2 products will be worth the work involved in implementing them. Some users will see the value immediately and step up to become lead implementers; others will feel that the change is unwelcome and unnecessary.

Create Strategic Packages

Key to visualizing a research product and its benefits is defining a product as a strategic grouping or packaging of multiple research results. Grouping related research results helps a user see how the research program as a whole has addressed an array of related concerns. It allows the user to focus on one system rather than a list of distinct products. Strategic packaging focuses on achieving a major objective of critical concern to the user rather than multiple subordinate objectives addressed by the individual research results. For example, the first SHRP encompassed more than 30 individual research projects related to improving asphalt pavements, including design methods, standards, and various pieces of equipment. These were packaged as one asphalt pavement design system—Superpave—that promised to save billions of dollars by increasing the life of asphalt pavements by 50 percent. Sometimes strategic packaging is achieved through the use of brief tag lines that condense a complex set of issues into an easily visualized goal. For example, a variety of different innovations aimed at snow and ice control prior to a snowfall, including snow fences, roadway sensors, plows, and forecasting methods, were subsumed by the phrase "get in under the storm." Similarly, the value of a wide array of materials, methods, and contracting approaches for achieving rapid infrastructure renewal is intuitively grasped under the phrase "get in, get out, stay out."

Lessons Learned from SHRP 1 Concerning Implementation Agents

Identify the Principal Implementation Agent Early

In the case of the first SHRP, the principal implementation agent, FHWA, was not identified until late in the research phase. FHWA received authorization and funding to carry out implementation activities only after the research was almost complete. Once the funding had been received, it took

some time for implementation activities to become operational. This made it impossible for the implementation agent to work alongside the researchers to understand the research results and possibly influence how they were packaged to maximize utility for potential users.

Cultivate an Array of Implementation Agents

While one agent may take the lead on implementation, any new technology will require the engagement of many users and stakeholders who must be persuaded and empowered to become implementation agents. Formal groups devoted to SHRP 1 implementation in FHWA, AASHTO, and TRB have already been mentioned. Clearly, these stakeholders must be actively engaged in implementing SHRP 2 results. However, many other groups must be brought to the table: local, regional, and state governments represented by the Association of Metropolitan Planning Organizations, the National Association of County Engineers, the American Public Works Association, the Governors Highway Safety Association, and the National Conference of State Legislatures; manufacturers and suppliers, such as the National Asphalt Pavement Association, the American Concrete Pavement Association, the National Steel Bridge Alliance, the National Concrete Bridge Council, the American Traffic Safety Services Association, the American Concrete Institute, and the Precast/Prestressed Concrete Institute; the construction industry, for example, through the American Road and Transportation Builders Association and Associated General Contractors; engineers and designers, through the American Society of Civil Engineers (ASCE), the Institute of Transportation Engineers (ITE), and the American Council of Engineering Companies; and environmental and highway user groups, such as the Surface Transportation Policy Partnership, the Nature Conservancy, the American Trucking Associations, the American Automobile Association, and the Highway Users Alliance. The roles of these groups will vary—from central to ancillary to no role at all—for different types of products.

Identify and Address the Concerns of Those Who May Resist Implementation

However obvious the benefits of an innovation may appear to be, there will always be some who fear—rightly or wrongly—that the change threatens

them or is not worth the cost of implementation. It is not always immediately apparent who the threatened parties will be in each case. Communicating early and often with the wide array of stakeholders mentioned above should help in identifying those who have concerns about the impact of a new way of doing things. These concerns need to be addressed early, openly and clearly. Sometimes there is no way to avoid a negative impact on some party, but often a mutual agreement can be reached that the innovation is beneficial for all parties or at least is not necessarily a threat to anyone.

Communicate Ceaselessly

Frequent updates should be provided to all interested parties. Even supportive stakeholders will need assistance in organizing themselves to facilitate implementation. The implementation of research results can take many years and a significant investment of resources, and it must continuously be accompanied by selling the benefits of the implementation. This is particularly true of research products or programs that are designed to last a long time. In the case of the Long-Term Pavement Performance (LTPP) Program, the selling effort faltered. The result was a significant reduction in funding because the importance of completing the 20-year program was not apparent to later generations of professionals who had not been involved at the program's inception. In SHRP 2, there will be a similar need for long-term support—not for research, but for the maintenance of products (such as software and databases) whose value will increase the more they are used and improved.

Lessons Learned from SHRP 1 Concerning Implementation Mechanisms

An array of mechanisms will be required to reach all the potential users and implementation agents of SHRP 2 products. Some examples from implementation of the first SHRP are listed here.

Make Use of Existing Mechanisms

Some groups already have mechanisms in place that SHRP 2 could tap and cultivate as implementation agents. For example, local governments and state DOTs use a network of technology transfer centers that participate in the federal Local Technical Assistance Program (LTAP) and Tribal Techni-

cal Assistance Program. LTAP centers are adept at delivering training and other forms of information to county and city transportation officials, as well as state DOT districts. Other institutions listed earlier have technical committees through which new technologies can be made known. Among them are AASHTO, ITE, TRB, and ASCE. FHWA's National Highway Institute is a well-established training function familiar to state DOTs and others. The Technology Curriculum Coordinating Committee coordinates training across state DOTs and handles certification requirements.

Investigate and Work Within Established Innovation Pathways

Certain types of innovations have established mechanisms or pathways that must be followed if widespread deployment is to be achieved. Highway construction materials are a good example. A state DOT will not use a material for which a standard does not exist. Other technologies also require or can benefit from the development of standards by formal standards-setting organizations, such as AASHTO, ITE, and ASTM. Some technologies, such as software and intelligent transportation systems, should be developed according to established architectures that ensure interoperability with other related technologies. Highway design innovations (geometric, safety, and operational) should be accepted into the Green Book, the *Highway Safety Manual,* the *Manual of Uniform Traffic Control Devices,* and the *Highway Capacity Manual.* Each of these standard design manuals is overseen by a formal committee or other group that must be engaged at the appropriate moment in the research process to ensure that the results will meet their requirements.

Develop New or Special Mechanisms Where Needed

In most cases, implementation of research is not the primary occupation of the potential user, and the temptation will be strong to leave the task entirely to existing committees and task forces that already have a full plate of other responsibilities. The AASHTO SHRP Implementation Task Force, the FHWA SHRP Working Groups, and the TRB SHRP and LTPP advisory committees are good examples of specially formed groups that focused on SHRP 1 implementation, a focus that included active coordination with all the relevant existing committees in their respective organizations. Reaching

some user groups may require the introduction of innovative mechanisms that do not currently exist. Developing partnerships with the private sector can be critical. Implementation of Superpave in the first SHRP required a close collaboration with the asphalt paving industry. User–producer groups were established to facilitate open communication and to solve problems and address issues from both sides. Awareness of market forces and how they might help or hinder the introduction of a new technology is critical. When an innovation clearly benefits the public or a state DOT but requires that the private sector take action (to manufacture a technology or put it into practice), the incentives or disincentives for the private sector must be considered. To demonstrate the use of "get in, get out, stay out" technologies, workshops were staged at which all the players (in design, traffic control, construction, and planning) could apply the technologies to actual roadways slated for renewal. The AASHTO SHRP Implementation Task Force established the Lead State Program, in which one or a few states stepped forward to be early adopters of particular SHRP 1 products and then provide peer support to other states that implemented the products later. A Local Products Committee was established to package and promote research products of particular relevance to county and city transportation professionals. Box 6-1 lists methods that were used in implementing the first SHRP.

Lessons Learned from SHRP 1 Concerning Resources

Implementation Costs Money

In the first SHRP, dedicated federal funding for implementation was approximately equal to the federal research investment; however, additional federal funds were spent to support SHRP 1 implementation. Implementation investments were also made by state DOTs, local governments, and the private sector. The costs involved include follow-on research to tailor original research results to specific situations, testing, demonstration projects, equipment purchases, training, development of standards, and much more. For agencies whose budgets are already stretched to the limit and that suffer from human resource shortages, implementation will necessarily require additional incentive funding and provision of expert consultation and support from outside the agency.

Box 6-1

EXAMPLES OF METHODS USED TO IMPLEMENT PRODUCTS OF THE FIRST SHRP

- Showcase contracts and workshops
- Test and evaluation projects
- Demonstration projects
- Speakers Bureau
- Success stories
- Provisional standards
- Lead states
- Product evaluation committees
- Equipment loaner program
- Rugged round-robin testing
- Pooled-fund equipment purchases
- User–producer groups
- Staff state visits
- Local Technical Assistance Program training
- Product catalogue with vendor sources
- National training center
- State coordinator structure
- Exhibits

SOURCE: TRB 1998.

Implementation Takes Time

The highway community is large, complex, and generally risk averse. Its members will usually be quick to implement small innovations with the promise of short-term benefits, but some time will be required to convince them to make the changes necessary to realize large, long-term benefits. The process of changing standards, practices, and attitudes can take years, especially when impacts on statutory authority, personnel requirements, and institutional structures are involved. It also takes time for university curricula to reflect innovative practices and new knowledge. In an effort to accelerate innovation, the National Highway Institute is developing a course to train highway professionals in a structured approach to implementation.

PRINCIPLES FOR SHRP 2 IMPLEMENTATION

The following principles can be drawn from the experience with implementing SHRP 1, and they form the basis for the strategies outlined in the next section.

Establish a Principal Implementation Agent as Early as Possible to Provide Clear Leadership and Dedicated Staff Support

SHRP 2 implementation will involve many research products being adopted by an array of organizations. Effective nationwide implementation will require sufficient human and financial resources and a principal implementation agent, that is, an organization that will lead and support SHRP 2 implementation. This organization should have a national scope, extensive knowledge of the highway field, experience with implementing research results and new technologies, established relationships with transportation agencies, and the ability to provide funding and technical support to state DOTs and other potential users of SHRP 2 products. The implementation agent should be identified as soon as possible, before the research program has been completed, to ensure a smooth transition from research to implementation. To paraphrase Feller (1987), the implementation agent will have several functional roles: adapter, demonstrator, and disseminator of innovations; capacity builder for agencies implementing innovations; and information disseminator, educator, and facilitator. In addition, the principal implementation agent will be responsible for tracking the progress of implementation. The purpose of measuring the status and performance of implementation efforts is twofold: to determine whether these efforts are making progress toward the goal of widespread implementation and ultimately toward achieving the desired outcomes, and to determine and document which methods work best for specific product–user combinations. Better-informed decision making enables efficient resource allocation and supports the overall goal of accelerating innovation.

Involve Stakeholders Throughout the Process

Users and others affected by SHRP 2 products or in a position to influence their acceptance should be involved in planning and carrying out implementation activities. Strong partnerships with and among stakeholders build trust and encourage implementation champions.

Each focus area within SHRP 2 has its own set of stakeholders. State DOTs and local transportation agencies build, operate, and maintain most of the nation's highway and road system and purchase and use many products of highway research, making them the primary stakeholders of products from the Renewal, Reliability, and Capacity focus areas. Other stakeholders include metropolitan planning organizations, federal agencies, contractors, standards-setting bodies, consultants, and equipment manufacturers. Decision makers at the state and local levels are important stakeholders across all four SHRP 2 focus areas because they determine whether to support the implementation of new technologies. Researchers from the academic, private, and public sectors will use the knowledge and data generated by SHRP 2, in particular the safety data, to further advance highway research and innovation and the development of new approaches or technologies to improve highway safety. Educators, including university professors and training professionals, will use SHRP 2 results from all four focus areas in updating their curricula and course work.

Identifying the primary users of a particular technology, as well as those who can be influential in its implementation, is critical to the ultimate success of SHRP 2 products. The ongoing involvement of many potential users in SHRP 2 research is a positive first step; it can be continued and broadened through pilot studies and demonstrations that will familiarize potential users with the products of the research and help researchers focus more clearly on the problems faced by users. Early involvement can also help implementation agents identify potential early adopters who can become strong supporters of or champions for specific technologies, as well as help select appropriate methods for transferring the technologies. Active involvement of stakeholders also builds trust—a fundamental element of successful implementation in the highway community. The risk-averse culture of the community, derived from its public responsibility and institutional incentives and disincentives accrued over the years, leads it to place much weight on trustworthy experts and on demonstrated experience before trying something new.

Communicate Ceaselessly

Implementation cannot be reduced to communication—it is not enough to market innovations or to publish reports—but is a critical component. It

is essential not only to provide information and answer questions but also to listen: to discern what users want, what they need but cannot articulate, where resistance may lie, and what positive lessons it can yield.

Communication must be a two-way process: the principal implementation agent must seek information from potential users about incentives and challenges they face and work cooperatively to leverage the incentives and overcome the challenges. The temptation to hear only from supportive stakeholders must be avoided; those who resist an innovation often have good reason for doing so, and much can be learned from them to make an innovation more attractive to more stakeholders. Communication must also be maintained throughout the implementation process. In addition to hearing about innovations when they first become available, stakeholders will want periodic updates on the progress of implementation; success stories; challenges overcome; and, most important, benefits achieved. Many communication mechanisms should be used to describe research results and products, to report on implementation activities, and to share information among users of SHRP 2 products. These mechanisms can include extensive electronic information in e-newsletters and searchable websites, face-to-face interaction in workshops and focus groups, webinars, and wikis (websites that allow users to add and edit content). Emerging transportation knowledge networks are an important potential resource for SHRP 2 communication and information sharing (TRB 2006).

Prioritize Products for Optimal Implementation Success

An early task is to identify SHRP 2 products with the most potential for successful implementation, where success means both widespread use and significant benefits. Feedback from the communication efforts discussed above should be used in the prioritization process to support the allocation of resources and inform decisions on how to support implementation. Setting and revising priorities are part of a continuing process that requires specific guidelines and procedures both to carry out the implementation effort and to monitor progress toward goals. Priority-setting guidelines form a framework for decision making. Such factors as the strategic goals of the U.S. Department of Transportation and AASHTO, expected technology benefits, the extent of user interest, the need for financial incentives, potential product commercialization, and opportunities for private-sector partnering can form

the basis for setting priorities. The principal implementation agent will have to make critical choices about where and how resources will be used. The priority-setting process should be transparent and based clearly on the input of key stakeholders, such as FHWA, state and local DOTs, and other potential supporters, and it should be subject to independent external review.

Market and Package Products to Facilitate User Acceptance

A large array of individual research products can be daunting for busy users to navigate. Packaging products that work together and branding systems or suites of products helps streamline users' understanding of the products and their benefits.

Choose the Right Implementation Strategies

The implementation strategies discussed in the next section have all shown themselves to be successful. However, this does not mean that every strategy is appropriate for every product or user audience. For example, materials technologies usually require consensus standards; construction technologies are well suited to demonstration projects; and computer programs require beta testing and user support. Likewise, different training programs are better at reaching different audiences. Some products call for more practical training, while other products require changes to university curricula. Industry structure and economic incentives can also influence the specific strategies adopted: some products may involve intellectual property that must be protected, some may attract interest in private-sector commercialization, and others will need more public-sector support. It is important that the principal implementation agent carefully study the SHRP 2 products and potential users to determine which strategies are most likely to be effective in each case.

Balance Divergent and Convergent Approaches

Successful innovation strategies should allow for and encourage both divergent and convergent approaches. Divergent approaches provide intellectual space and resources for ideas and experiments to follow different paths and make serendipitous discoveries, building on the knowledge produced by research. Investigator-driven research programs are examples of divergent

mechanisms. Convergent approaches focus on particular goals and objectives; plans, products, and resources are aligned with achievement of these objectives. Ultimately, innovation and widespread implementation involve an interplay between divergent and convergent approaches—openness to the unexpected as well as disciplined planning. As a general though somewhat oversimplified rule, the balance shifts from divergence to convergence as one moves along the continuum from basic research, to applied research, to development, to implementation. At no stage is one mode exclusively in play, however. In the case of SHRP 2 implementation, the products to be implemented will be given—the time for divergent ideas about what SHRP 2 research goals should be or what products should result will be past. SHRP 2 implementation will involve prioritization of activities, plans, and programs and allocation of budgets in accordance with these priorities. Nevertheless, there will be avenues of implementation and perhaps even users of SHRP 2 products that the managers of the implementation effort will not have foreseen. The program should be open to new paths when they arise and have sufficient flexibility in its planning and budgeting to take advantage of promising opportunities.

KEY IMPLEMENTATION STRATEGIES

Several key implementation strategies emerge from the experience with implementing SHRP 1, as reflected in the principles outlined above. To be successful, these strategies must be supported by a strong knowledge management infrastructure that provides tools and expertise, especially in the area of information technology (see Box 6-2). Two of the strategies discussed below—training and education and long-term stewardship of information repositories—are themselves key elements of knowledge management. All the strategies involve communication and collaboration among users and other stakeholders. The full range of knowledge management tools should be employed, as appropriate, to advance these strategies.

Strategic Packaging and Branding

As suggested above, the benefits of some SHRP 2 products may be optimized by combining the results of several related research projects into a unified package with unique branding, as was done for Superpave.

Box 6-2

KNOWLEDGE MANAGEMENT

Knowledge management is key to facilitating the translation of research results into successful implementation. It is a broad concept that encompasses access to and sharing of information, networking and collaboration, and stewardship and archiving of data and information. It is dynamic and responsive, going beyond informal, work group, and project exchange of knowledge. It includes repositories of written information, as well as the collective knowledge of individuals, together with methods for accessing the information. Organizations today recognize the need to go beyond traditional information-sharing methods to ensure that widely dispersed project teams can communicate and share essential information.

Knowledge management is supported by and carried out through an array of methods and technologies. These include traditional methods, such as classroom instruction, workshops, and other face-to-face learning and collaboration activities. Information technology tools can significantly increase the scope, scale, integration, and timeliness of these methods. Electronic databases and archives, including many that can be searched online, make entire libraries available. The Internet enables nearly instantaneous communication with colleagues around the world. Online conferencing tools, backboards, and wikis provide for information sharing and collaboration among dispersed individuals and groups and can be tailored to be as open or as restrictive as users wish.

The value of all these methods, whether traditional or high-tech, lies in their ability to promote and facilitate learning. When people are asked to change—as is often the case in improvement or technology adoption efforts—they are being asked to learn, not abandon what they have learned. The high failure rate of business process innovations [estimated at 70 percent (Wellins and Murphy 1995)] has been attributed in large part to the lack of a connection between technology adoption and learning. Paying attention to how people learn reinforces effective change management. Generally, learning takes place in organizations through training, professional development, lessons-learned documents, war stories, and knowledge or information repositories—all forms of knowledge management. Because people learn in different ways, there is room for many different knowledge management approaches in an implementation program. In the end, a learning organization must adopt good practice in teaming, education, information sharing,

(continued)

archiving of lessons, and corporate memory, all in a manner that is coherent yet streamlined and accessible.

A central principle of knowledge management is that organizations can foster the capture and exchange of knowledge through communities of practice—professional networks that identify issues, share approaches, and make the results available to others. A community of practice is a virtual community of members with similar interests and expertise connected electronically. Members of a community of practice can contribute papers, technical briefings, product evaluations, and other reports, as well as experiences, good practices, and information, to fill knowledge gaps. Such information is stored in the knowledge repository for the particular community and available to the members. Because the knowledge network is electronic, accessible at any time, and available to many, it can provide high-level service to its users.

Technical Assistance

Most of the implementation practices described here need to be accompanied by various forms of technical assistance. Users will require access to the skills and ongoing advice of persons with expertise related to each product or group of products arising from SHRP 2. Lead users may need assistance tailored to unique issues encountered by early users. The principal implementation agent for SHRP 2 will also need technical assistance in developing and delivering the implementation program. Websites, including wiki sites, and real-time, online expertise can provide technical assistance quickly when travel to a user's site is not really necessary.

Standards, Specifications, Guidebooks, and Manuals

Some products will not be used by public-sector agencies unless they conform to an established standard, are based on a specification that has been accepted in the industry, or are included in a standard design manual. Implementation of such products will require that SHRP 2 identify appropriate specifying or standards-setting organizations and work with them to convert research results into formal standards and specifications.

Follow-On Research, Testing, and Evaluation

However much effort is put into a research program of finite time and resources, there will always be areas in which additional research is needed to support implementation. Such research may be required in response to changing or unique user needs, unforeseen gaps in the research plan, or new opportunities. In addition, pilot testing and evaluation of research products may need to be conducted before products are ready for full-scale implementation.

Lead Users and Demonstration Projects

Certain products are complex enough that users will want to see a full-scale, real-world demonstration to be convinced that the products work. Demonstrations will be undertaken by lead users, who may also participate in other ways, such as training and giving advice to other users. Lead users will exhibit the innovation success factors discussed above. Innovative individuals can lead stakeholder groups and champion implementation in their own organizations. They can undertake demonstration projects and serve in roles similar to those of the Lead States in the first SHRP. Internet portals can be established to provide a space for lead users and other users to exchange experience and advice. Lead users who host demonstration projects may require financial assistance to cover the difference in cost, or delta cost, associated with demonstrating a new technology. Delta costs can include the increase in cost for first-time prefabrication of bridge or pavement systems, use of high-performance materials, purchase of equipment for nondestructive evaluation, mobilization of new equipment, and costs associated with increased contractor risk, among others.

Training and Education

Training and education are a necessary part of every implementation effort. Some SHRP 2 products will call for the development of new levels of expertise and skill beyond what standard training programs typically provide. Sabbatical opportunities, intensive summer courses, executive courses, and other techniques may be considered. New knowledge and practices resulting from SHRP 2 must be incorporated into university classrooms so future transportation professionals can become familiar with them from

the beginning of their careers. Use of webinars and other electronic tools can make training opportunities available to many more potential users without requiring them to travel.

Long-Term Stewardship

Certain products—such as databases, archives, software packages, and websites—require a long-term "owner" to maintain and update them and provide customer support.

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Abbreviations

FHWA	Federal Highway Administration
TRB	Transportation Research Board

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7 Implementation Approach for SHRP 2

A successful implementation program must be based on an in-depth, detailed analysis of products, users, market factors, incentives and barriers, benefits, and costs. A full analysis of these factors is beyond the scope of this report and is premature at this time because most of the SHRP 2 products are as yet incomplete. Nonetheless, it is possible to outline an implementation approach for SHRP 2 based on the principles and key strategies set forth in Chapter 6. This approach encompasses a principal implementation agent, application of the key implementation strategies to each of the four SHRP 2 focus areas, and an estimate of the financial resources required for the implementation effort.

PRINCIPAL IMPLEMENTATION AGENT: ATTRIBUTES AND ACTIVITIES

While many stakeholders will be involved in SHRP 2 implementation, the effectiveness of a coordinated implementation program depends in large part on a strong principal implementation agent. Chapter 8 presents the committee's specific recommendations with regard to the administrative structure of SHRP 2 implementation. This section provides a general outline of the tasks and responsibilities to be carried out in the administration of the program.

The mission of the principal implementation agent for SHRP 2 will be to promote and support the effective implementation of the program's products wherever these products can help achieve the goals of the Safety, Renewal, Reliability, and Capacity focus areas. With the principles of

successful implementation described in Chapter 6 as a foundation, this mission would be carried out through such actions as the following:

• Develop implementation plans for each SHRP 2 product or for groups of related products. These plans should include technical requirements, marketing and communication activities, budgets, timelines, milestones, performance measures, specific implementation mechanisms to be employed or activities to be undertaken, and stakeholders to be engaged. The plans should allow for divergent, serendipitous implementation. They should be living documents that are modified as circumstances require and incorporate lessons learned as the implementation program unfolds, and they should be made publicly available.

• Ensure that appropriate information technology (IT) and knowledge management[1] resources and expertise are made available. This provision is essential to facilitate the conversion of data and information from SHRP 2 research, especially the safety naturalistic driving study, into meaningful improvements in highway safety and performance.

• Assess the readiness for implementation of each SHRP 2 product. The following categories are illustrative of the potential stages of readiness:

- Products ready for immediate implementation;
- Products suitable for demonstration projects;
- Products requiring pilot testing, beta testing, or other formal evaluation; and
- Products requiring additional research.

• Package SHRP 2 products to maximize acceptance and usability. Branding of products may be appropriate in some cases.

• Identify the most effective implementation strategies and activities for each product.

• Administer competitive processes to provide for the additional research, testing, evaluation, demonstration projects, training, technical support, and other activities required to support implementation.

• Arrange for stakeholder involvement at the executive/strategic and technical/tactical levels throughout the program.

• Coordinate with other related programs and external stakeholder groups. Promote collaboration to expedite implementation, leverage resources, and increase the effectiveness of SHRP 2 products. Coordination

[1] Knowledge management is discussed in Box 6-2 in Chapter 6.

includes working with standards-setting organizations, stewards of professional and technical manuals and guidebooks, and providers of technical training and certification, as appropriate.

- Provide technical and, where appropriate, financial support to users, especially lead users. Technical support can include training, workshops, expert consultation, peer support services, printed and electronic information, and other aids.
- Track the progress of implementation, measure results, and report the results to stakeholders.
- Publish reports, manuals, guidebooks, websites, brochures, and other electronic and print products.
- Assist in the development or amendment of standards.

Effective administration of the SHRP 2 implementation program will depend on a strong partnership between the principal implementation agent and key stakeholders, including state and local transportation agencies and the academic and private-sector organizations that help these agencies achieve their transportation goals. Strong leadership, coupled with open communication and flexibility to respond to changing circumstances, new opportunities, and unexpected challenges, is critical.

Resource requirements are an essential consideration. In addition to the financial resources discussed later in this chapter, the importance of human resources in the principal implementation agent's organization cannot be overemphasized. The diversity of SHRP 2 products and the boldness of the new ideas they embody call for highly trained staff to plan and execute the implementation program. Implementation of innovations requires technical knowledge, good judgment about people and opportunities, communication and diplomatic skills, foresight, flexibility, and a willingness to become directly involved in real-world applications. It is a time- and people-intensive task that generally requires dedicated focus; implementation support is unlikely to thrive in competition with other work tasks. Implementation staff must be ready to act when an innovation becomes available and must have managers who understand their need to remain focused on implementation efforts.[2]

[2] It is understood that some of the implementation support work for SHRP 2 will be provided by contractors to the principal implementation agent. Nevertheless, these contractors should possess the characteristics described here and be managed by staff who share these characteristics.

IT and knowledge management are particularly important areas of expertise needed for effective implementation of SHRP 2. A number of products of the research, such as the safety database and the Collaborative Decision-Making Framework (CDMF), require IT infrastructure and services, including hardware, software, collaboration and communication technologies, and user support. Across the entire program, a wide variety of knowledge management tools and techniques will advance implementation. The principal implementation agent will need to have access to IT and knowledge management expertise and technologies.

One example of the importance of knowledge management is in the Safety focus area. The safety database will be a highly valuable resource for researchers and practitioners, but the value of the study is not in the accumulation of data. The study's value will be realized only through active management of the database and its availability to a broad range of researchers who will examine the data; search for patterns, connections, and priorities; convert the data into understanding of specific collision conditions; and identify potential countermeasures. This process will increase knowledge, and the application of this knowledge will improve roadway safety. This conversion of data to knowledge and insight is an example of knowledge management.

In addition to adequate quantity and quality of technical staff, administration of the SHRP 2 implementation program will require strong leadership. There must be a single point person at a high enough level in the institution to ensure that SHRP 2 implementation receives the necessary visibility and priority in the organization. While this person would ideally be fully dedicated to SHRP 2 implementation, it is conceivable that this dedicated role would be incompatible with a high-level position, depending on the institutional home of the principal implementation agent.

Those administering SHRP 2 implementation should recognize the diversity among the four focus areas while also exploiting their linkages or similarities in implementation needs. Each focus area has its own stakeholder communities, although there is some overlap. Certain implementation mechanisms will work well in one focus area and not in another. On the other hand, a mechanism that is traditional in one area may also turn out to be effective in another area, perhaps with some modification.

The temptation to align the four focus areas of SHRP 2 with four traditional management structures commonly found in highway agencies must

be resisted. The Safety focus area cannot be reduced to traditional roadway infrastructure safety because one of its salient characteristics is the integration of driver, roadway, and vehicle factors in highway safety. The Renewal focus area cannot be reduced to roads and bridges because the essence of the research approach involves such concepts as risk management, institutional strategies, and operational objectives in addition to infrastructure concerns. The Reliability focus area, while fitting squarely within the operations arena, takes a multifaceted approach to part of the operations mission—improving travel time reliability. If it is expected to address the full range of operations issues, it is likely to be deemed inadequate or to be diluted in its effectiveness. The Capacity focus area places strong emphasis on planning and environmental issues, but since these agency program areas have often suffered from the same fragmentation that occurs in their respective regulations and processes, implementation of SHRP 2 Capacity products will require breaking through both internal and external institutional barriers.

KEY IMPLEMENTATION STRATEGIES APPLIED TO SHRP 2 FOCUS AREAS

Chapter 6 outlined a number of key implementation strategies:

- Strategic packaging and branding;
- Technical assistance;
- Standards, specifications, guidebooks, and manuals;
- Follow-on research, testing, and evaluation;
- Lead users and demonstration projects;
- Training and education; and
- Long-term stewardship.

This section provides an overview of implementation approaches for each of the SHRP 2 focus areas, structured on the basis of these key strategies. Table 7-1 summarizes the major implementation activities under each key strategy that might be carried out for each focus area. Administration of the implementation program is presented as a cross-cutting activity because it would be carried out in a centralized manner, although each focus area could have some unique needs in this category. Technical assistance is also shown as cutting across the four areas, although the specific focus areas

TABLE 7-1 EXAMPLES OF MAJOR IMPLEMENTATION ACTIVITIES FOR EACH IMPLEMENTATION STRATEGY IN SHRP 2 FOCUS AREAS

Implementation Strategy	Safety	Renewal	Reliability	Capacity
Administration	This category covers all the activities that must be carried out across the implementation program, including contract management and support staff; oversight and technical committees; planning, analysis, evaluation, and performance measurement; IT and knowledge management infrastructure and expertise; and marketing, outreach, publication, and other communication activities. Administration would be carried out by the principal implementation agent.			
Strategic packaging and branding		Packaging and branding of technology and project delivery products	Packaging and branding of institutional, planning, programming, and design products	Branding of the CDMF
Technical assistance	Substantial technical assistance will be required in each focus area to make its products available to users. Such assistance would range from highly specific technical expertise to help users implement particular products to more wide-ranging assistance in change management for organizations that wish to make systemic improvements. A range of tools, from traditional on-site consultations to web-based assistance, should be used.			
Standards, specifications, guidelines, and manuals	Data standards for roadway data; guidelines for conduct of naturalistic driving studies; input to new safety initiatives from automobile manufacturers; input to safety initiatives of the Federal	Performance specifications, materials and equipment specifications, new designs, design examples, and construction details	Incorporation of travel time reliability into planning, design, and operations standards and manuals; standards for travel time data; model data-sharing agreements	Contributions to national travel forecasting handbook; handbooks for ecological and economic tools; standards for data needed to support tools and CDMF

	Highway Administration and possible regulatory initiatives of the National Highway Traffic Safety Administration			
Follow-on research, testing, and evaluation	Additional analyses using data from the SHRP 2 naturalistic driving study; characterization of collision load cases by type; assignment of frequency and cost and harm metrics to collision load case types; prioritization of research and countermeasure needs	Decision-making tools to aid agencies in the most effective use of products; research to adapt generic products to unique situations; pilot testing of new technologies; long-term evaluations; model validations	Pilot testing of institutional approaches and technical products; follow-on work for promising results of Innovations Deserving Exploratory Analysis and future-oriented Reliability projects; additional behavioral research using data from naturalistic driving studies	Benefit–cost analyses to demonstrate benefits of collaborative decision making; pilot testing of economic and travel modeling tools
Lead users and demonstration projects	Demonstration of site-based technology; use of advanced roadway data for safety planning; development of vehicle-based technologies for improved driver behaviors and performance; field studies to assess effectiveness and costs	Demonstration of individual products and integrated use of Renewal products by lead users; collaboration tools to enable lead users to assist other users	Demonstration of individual products and integrated use of Reliability products by lead users; collaboration tools to enable lead users to assist other users; deployment incentive programs	Demonstration of CDMF; collaboration tools to enable lead users to assist other users; demonstration of ecological approaches

(continued on next page)

TABLE 7-1 *(continued)* **EXAMPLES OF MAJOR IMPLEMENTATION ACTIVITIES FOR EACH IMPLEMENTATION STRATEGY IN SHRP 2 FOCUS AREAS**

Implementation Strategy	Safety	Renewal	Reliability	Capacity
Training and education	Workshops, stipends, sabbatical opportunities; materials for graduate curricula in highway safety and human factors; tools to enable researchers to share new analytical techniques	Workshops for practitioners; material for National Highway Institute, Local Technical Assistance Program, and online training; material for university curricula	Incident response training and pursuit of possible certification; training in use of planning and design manuals and models; training in use of data from naturalistic driving studies for travel time reliability efforts	Training in use of CDMF and ecological, economic, and travel modeling tools; curricula for graduate programs in planning
Long-term stewardship	Stewardship of data from the SHRP 2 naturalistic driving study, including oversight committee; availability of data to researchers in remote locations		Institutional structure for travel time reliability data archive	Stewardship of CDMF, including oversight committee; mechanism to add cases to economic case-based reasoning tool, including advisory body

will require differing technical expertise. IT and knowledge management activities are required across all strategies. IT support and cross-cutting knowledge management capabilities are included under administration of the program. These capabilities include, for example, the capacity to set up Internet-based communication and collaboration tools such as webinars and wikis; development of communities of practice; and the means to capture learning and knowledge gleaned both in individual focus areas and about implementation itself. Certain aspects of knowledge management are highlighted under training and education and long-term stewardship to call attention to specific needs in each of the focus areas.

Safety Implementation Approach

Naturalistic Driving Study Data

The principal product of SHRP 2 Safety research will be data from the naturalistic driving study. This product differs from most of the other SHRP 2 products in that the data will not directly affect highway practice but will be used by researchers and analysts to develop and improve safety countermeasures. The direct users of the data will be researchers in the academic, private, and public sectors; highway practitioners will be indirect users in that they will make decisions about the application of safety countermeasures on the basis of analyses of the data. For this reason, the Safety implementation approach focuses on ways to make the data accessible and usable for improving actual safety outcomes.

Long-Term Stewardship First and foremost, a mechanism must be established to house and maintain the raw data and the data sets that will be derived from the raw data. The intent behind this data resource center is to make all the data available to qualified researchers. Because data of a private nature, such as video of the faces of the volunteer drivers, will be included in the raw data set, safeguards must be instituted to prevent such data from being accessed by unauthorized persons. Future researchers desiring access to the data will have to meet all requirements included in the consent forms signed by the volunteers and will most likely need to submit their research plans to an institutional review board (IRB) for research involving human subjects. Therefore, procedures must be established to provide for IRB oversight and allow for secure authorized access to private

or sensitive data. Meeting this need may mean having a secure physical location to which authorized researchers will go to view data that cannot be released from the database. A tiered approach to data access—with more open access to less sensitive data and more stringent credentialing for access to more sensitive data—could be considered. An independent oversight group could be charged with ensuring that the scientific objectives and ethical commitments associated with the naturalistic driving study are preserved and promoted in future use of the data.

Technical Assistance To carry out all these tasks, a stable funding stream is needed, and an appropriate entity or institution must be identified to provide database administration, data reduction, technical support, training, and other services that will ensure the availability, usability, integrity, and security of the data. The magnitude of the task and the need for periodic upgrades to hardware and software necessitate a stable, reliable, multiyear funding stream that is not dependent on annual decisions or individual project support. This funding would support maintenance of the data center, periodic upgrades, basic staff and services, communication and outreach activities, some level of ongoing analytical work, and publication of results. Because it is expected that public, private, and academic researchers will want to make use of this national resource beyond a basic level of analysis using reduced data sets, the entity responsible for the data center should be able to receive further funding from these sources as fees for additional services provided.

Follow-On Research, Testing, and Evaluation The raw data alone from this project are expected to amount to nearly one petabyte (1,024 terabytes). To be maximally useful to the largest number of safety researchers and professionals, the raw data will need to be reduced and stored in smaller, more manageable databases. Some of this reduction will take place under SHRP 2 through the analysis projects focused on high-priority safety questions, but much more work will need to be done after SHRP 2 has ended. Funding for additional studies to answer more of the safety questions identified under SHRP 2 for which funding was insufficient would accelerate the application of the data to actual safety improvements. The full implementation program should include additional support for research and development

efforts aimed at quickly instituting highly cost-effective safety countermeasures, which would, in effect, pave the way for a wide range of companion efforts that could be funded from other sources. Research partnerships with government and industry, including automobile manufacturers and suppliers, as well as with academic and public health institutions, will make it possible to identify safety priorities, propose countermeasures, and assess the potential benefits of deploying those countermeasures and the possible need for voluntary or regulatory initiatives to implement findings from applied research.

Training and Education Potential users need to know about the availability of these data and their usefulness. Training must be provided so that researchers can become familiar with the new data and analytical techniques and the research community can access and use the databases to convert the data into insight and knowledge. In addition to traditional classroom and online training courses, training approaches may include short sabbaticals for visiting professors to work at the data resource center, stipends for graduate students who wish to focus their research on naturalistic driving, and the development of curricula and classroom materials for use by professors in university courses on highway safety and human factors. State and local agency highway safety professionals may have limited time for training, and many of them will not be interested in delving into the safety databases directly. Therefore, special outreach and training should be developed to focus on the needs and interests of these individuals—for example, how the data can be used to answer practical safety questions, how this type of research can expand horizons for asking new questions and developing new kinds of safety countermeasures and strategies, and how these professionals can work with their local universities and research firms to extract what they need from the existing data or even to conduct smaller-scale studies in their own jurisdictions.

Research Analysis Tools

The implementation of research analysis tools will take place in part through the normal academic channels of refereed journals, presentations at conferences by the researchers who develop the tools, and the application of the tools by automobile manufacturers and technology suppliers

seeking opportunities for safety improvements. However, special training and education efforts, such as workshops and hands-on use of the databases, would accelerate the process of familiarizing researchers with the data and methods for accessing and analyzing them. As researchers develop such methods, mechanisms will be needed for collecting and documenting them, making researchers aware of them, and incorporating them into ongoing training and workshop opportunities and the dissemination of significant findings.

Site-Based Video System

Several implementation practices should be applied to promote the site-based video system.

Follow-On Research, Testing, and Evaluation The most helpful next step to take for the site-based video system is to fund follow-on field studies and analyses to demonstrate the technology and produce actual results that safety professionals can use. The original SHRP 2 plan included projects that would have addressed these objectives had sufficient funds been available.

Lead Users and Demonstration Projects A number of field deployments of the system, focused on high-priority safety concerns such as intersection crashes, would promote use of the technology. Any use of a new system, especially in a field setting, will encounter unexpected snags and require adjustments for specific contexts. Early demonstration projects would help work out the practical bugs and identify some types of site-specific adjustments that may be required. If focused funding for these tasks were not forthcoming under a SHRP 2 implementation program, they would have to be carried out piecemeal as other sources of funding became available. This process would certainly take longer, and the work might not focus on safety questions of more general interest beyond those of concern to the individual researchers' sponsoring entities. Implementation of the site-based video system may be an ideal candidate for a lead state approach. Under this approach, a few states that were willing to become early adopters of the technology could be provided with funding and technical assistance to develop some expertise in the tool's use and then facilitate its implementation by other states through training and peer advice.

Training and Education In addition to analysis and demonstration projects, implementation of the site-based video system will require specialized training in its use.

Roadway Data Collection

Implementation of the roadway data collection component of SHRP 2 could involve the development of data standards for roadway data to be used in safety and other applications, such as asset management. These standards would call for greater accuracy or more data elements, or both, than characterize the current state of the practice in roadway data collection. Consensus-based standards would promote broader use of these higher-quality data that would be better suited to safety analyses. If the usefulness of these data is to be demonstrated, they will have to be used successfully to answer questions that could not be answered without them. Support might be provided for several states that already collect the data to demonstrate the use of the data in the states' strategic highway safety plans.

Renewal Implementation Approach

The context in which implementation of Renewal products will take place is characterized by a traditional highway design and construction audience with a nontraditional need—to renew an entire system of highways under heavy use. Traditional approaches to renewal have already led to some piecemeal use of innovative technologies, and a few high-profile projects have implemented several innovations at once. However, the most powerful benefits of this research will be achieved through consistent and systematic application of the products across an agency's entire program. Achieving this objective will require nontraditional approaches and a commitment to organizational change by public agencies and other project owners. The following implementation approaches can be effective in promoting the use of strategic packages of Renewal products.

Strategic Packaging and Branding

The first implementation strategy for Renewal products should be to package them in such a way that they form and are understood by users to be part of an integrated approach to highway renewal, rather than a series

of unrelated outcomes. For example, new materials, performance specifications, and nondestructive evaluation (NDE) technologies are a suite of products with a natural synergy. To these products could be added design procedures that support their integration, as well as products that broaden the technical focus to include institutions and community interaction.

Standards Development

Many Renewal products will require design and construction standards, materials specifications, and test methods. The principal implementation agent should work with the appropriate standards-setting organizations to ensure that SHRP 2 products undergo the procedures necessary to develop standards, specifications, and test methods that will be accepted by users.

Follow-On Research, Testing, and Evaluation

Pilot tests can be used when a strategy, technique, or technology has proved itself in theory or in the laboratory but has seen little use in practical applications. For example, some of the innovative bridge technologies developed in the Renewal program need to be tested in a real-world environment, but one that is more controlled than a full-scale bridge project. This type of project would provide an opportunity to refine the research results into a more robust innovation that is ready for demonstration projects. Performance evaluation and data collection will play a significant role in the long-term acceptance of the NDE techniques, design procedures, and analytical models developed under the SHRP 2 Renewal program. Projects incorporating SHRP 2 pavement or bridge products could be monitored under the Federal Highway Administration's (FHWA's) Long-Term Pavement Performance and Long-Term Bridge Performance Programs.

Lead Users and Demonstration Projects

Lead states that will play the role of early adopters must be identified. Renewal technologies, techniques, and strategies can be highlighted in lead states through demonstration projects, which provide an opportunity for stakeholders to see real-world examples of how those technologies, techniques, and strategies work. This approach is often helpful when an innovation has been proved but has not begun to diffuse because it is not

well known among practitioners. Competitive processes should be used to determine where such demonstrations will be carried out to ensure that the most appropriate site is chosen for a given technology or strategy. In addition to the training received for projects in their state, lead states can be trained to provide support to later adopters. They should also receive some funds to cover the delta costs associated with being early users of innovative products.

Training and Education

Training and education programs will need to be developed for public agencies and the private sector to produce the knowledge and skills necessary to implement Renewal products. The training could include workshops on tools that can assist public agencies throughout the decision-making process. The training materials will need to be tailored to the intended audience and could include both traditional classroom approaches and web-based methods. The training could be administered through the National Highway Institute (NHI) or the Local Technical Assistance Program centers.

Reliability Implementation Approach

Reliability is the area of SHRP 2 research most directly oriented toward the users of the highway system, but it involves some of the more complex concepts, strategies, and implementation paths. While concepts such as “congestion” and “being late for work” are readily grasped, “travel time reliability” requires some explanation. The wide variety of users and stakeholders for Reliability products increases the implementation challenge. Leaders of transportation agencies, technical experts, nontransportation professionals, and researchers will each need different types of information and outreach. In addition to these direct users of SHRP 2 Reliability products, many others may be indirect users or beneficiaries of improved travel time reliability. For example, buses operate in the same congestion that plagues cars; operators of bus transit systems are among the customers of highway agencies and are potential users of travel time reliability tools. Freight shippers and truckers are also customers of the highway system and are often sensitive to changes in travel time reliability. Examples of implementation strategies for the Reliability program are described below.

Strategic Packaging and Branding

As is the case with Renewal products, implementation of Reliability products will yield maximum benefits when the products are used together as part of an integrated, systemic approach that includes institutional, analytical, and technological components. Packaging and possibly branding these components will facilitate users' understanding of the overall benefits of the products. Leaders of transportation agencies in particular will need clear articulation of the performance benefits of managing nonrecurring incidents; a laundry list of research products will not impress them. A focus on decision-making tools that can help determine which reliability strategies to use may be most meaningful for this audience. The packaging effort might include outlining one or more incremental implementation strategies that can show clear impacts on customer outcomes; such an incremental approach to implementation would be less daunting to many organizations. Special packaging or branding may be needed to attract the attention and support of nontransportation professionals, such as police, firefighters, emergency medical teams, special event managers, and others who are affected by reliability but do not consider highway operations to be their primary concern. Packaging for the public safety community, for example, might focus on increasing awareness of the safety implications of better incident management and response and of the opportunities for achieving better performance in this area.

Standards, Specifications, Guidebooks, and Manuals

Transportation professionals rely on dependable guidelines and sources of information to carry out their work. To the extent possible, changes in planning, design, or field procedures need to be incorporated into standard references or models with which these professionals are familiar. In the design area, the *Highway Capacity Manual* and the American Association of State Highway and Transportation Officials' *Policy on Geometric Design of Highways and Streets* have already been identified as standard sources into which SHRP 2 Reliability results may be incorporated. The committees responsible for these documents must be engaged from the beginning of the research efforts in this area. If new guidelines or models must be developed, they must be "owned" by an institution that can stand behind their quality and ensure their long-term support and improvement. New or modified design

documents and planning models must be supported by training that is tailored to the needs and circumstances of each user group. Reliability depends on accurate and timely data about traffic flow and roadway conditions. In some cases, states will need to collect new data in order to use a new design approach or planning model; guidance on what data are needed and how they can be acquired should be provided. In other cases, appropriate data may be available from the private sector. Guidance on how to obtain these data and model data-sharing agreements should be produced.

Follow-On Research, Testing, and Evaluation

Technical products, such as analytical methods for determining the impacts of various operations strategies on travel time reliability, should be pilot tested before being made widely available. New institutional approaches can be pilot tested by more innovation-oriented agencies. Innovations Deserving Exploratory Analysis projects addressing reliability may require additional research, development, and testing. Follow-up research can be conducted to identify the implications of future-oriented concepts developed under the Reliability program and to elicit operations-relevant insights from the driver behavior data collected in the Safety focus area of SHRP 2.

Lead Users and Demonstration Projects

Deployment incentive programs could be developed for which transportation agencies and their partner organizations could compete. Such programs would provide some funding, training, and technical support for agencies that are prepared to engage in bolder implementation efforts using more integrated sets of Reliability products. The agencies that won these competitions would become lead users who would provide peer assistance to other agencies wishing to implement the demonstrated products. A special component of this peer support could be focused on agency leaders—secretaries and directors of transportation—to assist them in fostering institutional change to achieve better operational performance.

Training and Education

Accomplishing the objectives of the SHRP 2 Reliability focus area will entail a profound change in the way transportation agencies understand and carry

out their mission. This change is often characterized as a shift from a focus on designing and building infrastructure to a focus on providing mobility and accessibility, which includes managing operations and information in addition to constructing and maintaining facilities. Such a shift requires transportation professionals to think in terms of random events, probability distributions, and statistical measures. For agencies to incorporate reliability performance measures into plans, program assessments, operations, and decision-support tools, they must begin to think of their system in statistical terms. Education and training programs that communicate the basic concepts of reliability, as well as more in-depth and practical results of the SHRP 2 Reliability research program, will be essential. These education and training courses might be offered through NHI, the Operations Academy,[3] executive short courses, and a variety of online courses. Specialized training will be required for practitioners to learn how reliability concepts can influence their daily work. Universities will need to teach these concepts to future transportation professionals so they start their careers with an operations mentality. In the area of incident response, SHRP 2 is developing joint training for responders from within and outside of transportation agencies. Methods to support implementation in these communities should make the fullest possible use of organizations trusted by these practitioners. Incident response training may need to be integrated into existing training programs for each group (e.g., police, firefighters). However, common training of diverse groups can lead to better teamwork in the field. Such common training would need to be organized and carried out by an appropriate institution or organization respected by all the incident response constituents. Differences in institutional cultures call for careful, step-by-step implementation strategies that respect each culture's specific requirements.

Long-Term Stewardship

Researchers and analysts will want to use data contained in the travel time reliability data archive being developed under the Reliability program. The data archive must have stable ownership and funding. The costs of maintaining large data archives and providing services to data users can be sub-

[3] The Operations Academy is an intensive, 2-week program sponsored by the I-95 Corridor Coalition that trains transportation professionals in surface transportation management and operations.

stantial; few if any institutions would be able to absorb these responsibilities without additional revenue. Training in the use of these data resources will also be necessary.

Capacity Implementation Approach

Collaborative Decision-Making Framework

The principal product of SHRP 2 Capacity research is CDMF. Several implementation practices for CDMF are described below; the two most critical are establishment of long-term administrative and technical stewardship for the framework and its tools, and demonstration of its effectiveness in real-world applications.

Strategic Packaging and Branding "Collaborative Decision-Making Framework" has been the working name for this product, but it may be helpful to develop a shorter "brand name" that communicates the essential philosophy of the approach. Communication and marketing efforts should be undertaken to create broader awareness of CDMF among prospective users and other stakeholders.

Follow-On Research, Testing, and Evaluation Follow-on research should develop accounting approaches to show the costs and benefits of CDMF. Benefits will include reduced delay in delivering projects because of less opposition from community and environmental groups and less risk of lawsuits.

Lead Users and Demonstration Projects Competitively awarded demonstration projects should be conducted in a small number of states that are willing to act as lead users of CDMF. These projects would involve working with the framework and observing the results and changes in an agency's business processes that may ensue. Funding should be provided to these lead users to cover training and delta costs associated with the demonstration projects.

Training and Education Training will be required to help users reap the greatest benefits from CDMF. The training could be provided at two levels: to support managing change within a department of transportation (DOT) or metropolitan planning organization and with partner agencies, and to support use of CDMF, especially for high-risk key decision points.

Long-Term Stewardship CDMF requires an "owner" to maintain, make available, and update its documents and electronic resources. The owner will need to establish an oversight committee of users, manage the website that contains the electronic version of the framework, perform updates as needed, and engage in continuing outreach. The costs associated with these tasks include provision and support of an electronic, web-based platform; staffing of a board charged with oversight, deployment, and updating of CDMF; marketing and outreach; staff time; periodic updates and revisions; and training.

Ecological, Travel Behavior, and Economic Impact Theme Areas

Implementation of products in the other three theme areas of Capacity research—ecological, travel behavior, and economic impact tools—can be promoted in concert with that of CDMF. These products can also be implemented as independent sets of tools. In all three areas, the following implementation approaches would be useful.

Lead Users and Demonstration Projects Lead agencies should be identified that are willing to demonstrate the tools in one or more of the three areas, document the process and its outcomes, and provide peer support for other agencies interested in adopting the demonstrated tools.

Training and Education Specific training should be developed in use of the tools in each of the three areas. Mechanisms should be developed for delivering this training to public- and private-sector agencies. A national travel forecasting handbook has been proposed by FHWA; SHRP 2 could contribute to this handbook. Similar handbooks may be useful in the ecological and economic areas. Implementation of the economic impact tools would also benefit from training in communicating the results of such analysis to decision makers and the public. Relevant stakeholders, such as the environmental community and groups interested in travel behavior modeling or economic development, should be targeted for outreach. Communication with these stakeholders should be repeated and sustained, making use of existing meetings and conferences as well as specialized focus groups to identify their interests and address their concerns. As a cadre of stakeholders becomes convinced of the benefits of the Capacity products, specialized workshops and training can be developed and provided.

Long-Term Stewardship The economic impact tools of SHRP 2 would increase greatly in value if a mechanism were developed for adding new cases to the case-based segment. To this end, an owner or steward of the product would need to provide a method for users to add cases, as well as trained staff to review and edit the cases and integrate them into the product.

FINANCIAL RESOURCES

Good estimates of the cost of implementing research products are difficult to derive. Different terminology is used in different industries; the boundaries between research and development and between development and field trials or demonstrations are not clearly or consistently defined. The private sector often considers breakdowns of these costs to be proprietary information. The costs of implementation are sometimes borne by numerous entities, so reports from one source may underestimate the real costs. An "off-the-record" estimate from a major U.S. firm set the cost of the implementation phase of new product development at approximately 10 times the cost of research.

In the case of the first SHRP, approximately $150 million (1991 dollars) was appropriated for FHWA specifically for the first 6 years of the implementation effort; this figure is equivalent to nearly $240 million in 2008 dollars. Additional federal support for SHRP 1 implementation came from other FHWA discretionary research and technology funds but was not tracked by the agency as SHRP 1 implementation spending. Estimates of federal support are only part of the equation. The National Cooperative Highway Research Program (NCHRP) contributed $14 million to SHRP 1 implementation when federal funds proved insufficient. No comprehensive data are available, but anecdotal accounts from state and federal officials suggest that state DOTs spent at least as much in state funds to implement the results of SHRP 1 as FHWA spent in federal funds.

Inasmuch as this report was requested by Congress, the committee confines itself to assessing the financial requirements for SHRP 2 implementation that would most appropriately be provided at the federal level. These are costs that individual users would find difficult or impossible to bear or that would be handled more effectively in a centralized manner. Table 7-2 provides rough estimates of required federal funding for SHRP 2 implementation over a 6-year period for each key implementation strategy. These budget estimates were developed by assessing the implementation needs of

TABLE 7-2 ESTIMATED COSTS FOR KEY IMPLEMENTATION STRATEGIES

Key Implementation Strategy	Estimated Cost over 6 Years (millions of dollars)
Administration of the implementation program, including funding for contract management and support staff; oversight and technical committees; planning, analysis, evaluation, and performance measurement; IT and knowledge management infrastructure and expertise; marketing, outreach, publication, and other communication activities, including strategic packaging and branding	63
Technical assistance contracts	68
Support for development of standards, guidelines, and manuals	23
Support for follow-on research and pilot testing to refine and assess SHRP 2 research products	63
Technical and financial support for demonstration projects and for lead users who host these products and provide peer support to other users	51
Development and delivery of training and education	46
Provision of long-term stewardship of tools, models, databases, and archives as national resources; focused oversight committees	86
Total estimate	400

each focus area on the basis of the anticipated products listed in Appendix B, the example activities in Table 7-1, and cost estimates from similar federal and Transportation Research Board programs, adjusted for inflation. The line items in Table 7-2 include the following components:

• Administration—staff for all four focus areas, as well as management and support staff for the program as a whole; communication and marketing; publications; travel, committee support, meetings, and international coordination; knowledge management and information technology; evaluation and performance measurement;

• Technical assistance—one or two contracts per focus area to augment technical expertise at the principal implementation agent's organization;

• Development of standards, guidelines, and manuals—an estimated 40 documents of this type;

• Follow-on research and pilot testing—an estimated 60 research projects and 60 pilot tests;

• Demonstration projects—an estimated 40 demonstration projects and support for 100 lead users;

• Training and education—courses, curriculum materials, workshops, and stipends for academic sabbaticals; and

• Long-term stewardship—the safety database and approximately three other major databases, and 15 minor databases or software products.

The scale of the work—including estimates of full-time equivalent positions; of numbers of committees, meetings, and publications; and of the size of technical assistance contracts—is based on estimates from people involved in implementation of the first SHRP. Estimates for the development of standards, guidelines, and follow-on research are based on typical projects from NCHRP. Estimates for demonstration projects and for development of manuals and training courses were provided by FHWA staff. Costs for the first 6 years of stewardship for the safety database are based on estimates provided by Virginia Tech Transportation Institute and the National Highway Traffic Safety Administration (NHTSA); these estimates were modified to provide estimates for similar activities in the other focus areas. The committee also took into consideration the reduction in FHWA staff since SHRP 1 implementation, which means that a higher proportion of staff support for SHRP 2 implementation would likely come from contractors. Contractor expenses would be covered by funding for the SHRP 2 implementation program, while FHWA salaries are funded from a separate source. The combination of a bottom-up estimate based on expected products and required implementation activities and a rough comparison with implementation costs for the first SHRP, taking into consideration the differences between SHRP 1 and SHRP 2 and adjusting for inflation, led the committee to conclude that an overall estimate of $400 million in federal funds for SHRP 2 implementation is reasonable.

To put this cost estimate in perspective in terms of the potential benefits to society, if implementation of SHRP 2 research reduced congestion by just 1 percent, $780 million would be saved in a single year—nearly twice the recommended total funding for SHRP 2 implementation. Every 1 percent

reduction in congestion would also save 42 million person-hours, or nearly 4,800 person-years, and 29 million gallons of fuel. Similarly, every 1 percent improvement in highway safety from implementation of SHRP 2 research would save more than 400 lives, avoid more than 25,000 injuries, and save $2.3 billion in costs associated with injuries and deaths annually. And implementation of SHRP 2 can be expected to yield much more than the 1 percent improvement used for these examples. (Estimates are based on data given by Blincoe et al. 2002 and TTI 2007, Exhibit B-11, p. B-19.)

The 6-year costs shown in Table 7-2 are predicated on the assumption that the next surface transportation authorization will cover a period of this length. Implementation of all SHRP 2 products is unlikely to be completed within this time frame. It took approximately 15 years for the main product of the first SHRP, Superpave, to be adopted by all the state DOTs. A similar time frame may be expected for implementation of some of the bolder or more comprehensive products of SHRP 2. Implementation costs after the 6-year period should be assessed by the principal implementation agent when it is timely to do so.

Products requiring long-term stewardship, such as the safety data and CDMF, will continue to require funding for maintenance, updating, and provision of customer services. Funding for these products beyond the next authorization period should be reassessed toward the end of the authorization cycle on the basis of demand for the products and benefits to be achieved through appropriate federal support. The safety database, given its size and the variety and characteristics of the data it contains (most of the data will be in video form), will require significant support to ensure its effective application in addressing safety needs. Preliminary estimates from NHTSA and Virginia Tech Transportation Institute for basic stewardship of the safety database are in the range of $30 million to $35 million for 6 years.[4] These estimates do not include additional analysis, new data reduction, training, or other specialized user support, which are essential to making these data as available and useful as possible. Costs for the long-term stewardship of other SHRP 2 products, such as CDMF and the reliability data archive, should be significantly lower than those estimated for the safety databases.

[4] Note that the figure for long-term stewardship in Table 7-2 is for databases and archives across all four focus areas of SHRP 2 and includes funds for focused committees to oversee the databases, as well as some funding for additional user support.

REFERENCES

Abbreviation

TTI Texas Transportation Institute

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TTI. 2007. *2007 Urban Mobility Report.* http://mobility.tamu.edu/ums/.

8 Recommendations

As of this writing, research projects in the second Strategic Highway Research Program (SHRP 2) had been under way for less than 2 years of the program's projected 7-year duration. Preliminary results indicate that SHRP 2 research products will contribute substantially to addressing some of the most salient challenges facing highway transportation. Widespread implementation of these products promises to deliver on the overarching goal of SHRP 2: providing outstanding customer service for the 21st century. In view of the findings documented in this report, the committee makes the recommendations presented below. These recommendations are rooted in the principles and strategies outlined in Chapter 6 and should be understood in that context.

Recommendation 1: A SHRP 2 implementation program should be established.

A robust and comprehensive effort to implement the products of SHRP 2 should address all four focus areas: Safety, Renewal, Reliability, and Capacity. The program should use demonstrated implementation strategies, including those described in Chapter 7, as well as other innovative approaches that may be developed. Lessons learned from implementation of the first SHRP can serve as a good starting point, keeping in mind that SHRP 2 differs from SHRP 1 in some significant ways: it addresses a broader array of research topics, encompasses disciplines not traditionally involved in highway research, and engages stakeholders external to the highway community per se. These differences call for new implementation approaches in addition to those that

were effective in implementing the first SHRP. Beyond engaging state departments of transportation (DOTs), which remain the primary user group, mechanisms must be established to engage metropolitan planning organizations and local governments, law enforcement, firefighters, emergency medical services, railroads, utility companies, automobile manufacturers, university researchers, and others, depending on the specific products under consideration. SHRP 2 implementation should also be coordinated with other technology transfer and dissemination processes, even as a focus on the uniqueness and branding potential of SHRP 2 products is maintained.

> **Recommendation 2:** The Federal Highway Administration (FHWA) should serve as the principal implementation agent for SHRP 2, in partnership with the American Association of State Highway and Transportation Officials (AASHTO), the National Highway Traffic Safety Administration (NHTSA), and the Transportation Research Board (TRB). NHTSA should exercise a leadership role in the long-term stewardship of the safety database.

The SHRP 2 implementation agent should have a national scope, extensive knowledge of the highway field, experience with implementing research results and new technologies, established relationships with transportation agencies, and the ability to provide funding and technical support to state DOTs and other potential users of SHRP 2 products. The committee considered three organizations of national scope as candidates for this role: FHWA, AASHTO, and TRB. All three organizations are active in promoting highway innovation; all have experienced staff and access to potential users of SHRP 2 results. TRB and AASHTO have relatively small staffs, nearly all of whom are located in the Washington, D.C., area. Either organization would need to undergo significant restructuring to administer the SHRP 2 implementation program, including hiring many new staff and establishing a presence or mechanisms to provide timely, on-site support to users of SHRP 2 products throughout the country.

Promoting technology has been central to FHWA's mission since its earliest predecessor agency, the Office of Road Inquiry, was established in 1893. It has long-established relationships with state DOTs, including field offices in each state with staff who work closely with state DOT staff, in addition to expertise in Washington and a multidisciplinary highway research center in

Virginia. The agency's expertise encompasses most of the major disciplinary areas covered by SHRP 2: highway planning, design, and construction; environmental and safety concerns; and highway operations. In addition to being able to provide funding and technical assistance to state and local transportation agencies, FHWA can modify or waive regulations to facilitate testing and implementation of new technologies and methods.

FHWA administered a successful implementation effort for the first SHRP and learned many practical lessons from that experience. The committee believes the agency is best positioned to administer SHRP 2 implementation as long as it takes into consideration the specific differences between SHRP 1 and SHRP 2, as well as the unique challenges facing SHRP 2 implementation. The agency will need to engage in some reorganization to provide dedicated management and technical support for SHRP 2 implementation. It may need to recruit additional expertise or technical expertise different from that which is currently available among its staff and contractors.

While many stakeholders will be involved in the implementation program, several stand out as potential partners. Primary among these is AASHTO, because the state DOTs remain the principal user group. AASHTO can also play an important role in setting standards to facilitate adoption of innovations by both state and local government transportation agencies. TRB's involvement is based on its current role in administering the research program and on its network of technical committees; its other communication and coordination mechanisms; and its ability to establish high-level advisory, oversight, and technical committees. The Safety component of SHRP 2 calls for a strong role for NHTSA. As the principal implementation agent, FHWA should consider funding senior staff at other organizations to serve as point persons for SHRP 2 implementation and to coordinate their organizations' activities with FHWA. AASHTO, NHTSA, and TRB are among the organizations in which such a position could be beneficial.

Chapter 7 outlines the key attributes and activities of the proposed SHRP 2 principal implementation agent, which the committee believes FHWA should consider in establishing the implementation program. The committee wishes to emphasize three of those attributes here:

• *Adequate dedicated staff:* FHWA will need sufficient staff with appropriate technical and managerial expertise to guide the program successfully, providing support to volunteer stakeholders and overseeing the technical

activities of other staff, contractors, and lead users of research products. In addition to technical expertise in the four SHRP 2 focus areas, FHWA will need to tap expertise in information technology (IT) and knowledge management.

• *High-intensity focus to expedite implementation:* The benefits promised by SHRP 2 research are urgently needed. FHWA must be prepared to give the implementation program top priority and establish mechanisms for expediting key supporting activities, such as forming stakeholder groups; executing contracts and other agreements; establishing communication mechanisms; initiating field demonstrations; and publishing usable manuals, guidelines, databases, and other products.

• *Appropriate quality control mechanisms:* To the extent practical, competitive processes and merit review should be used to select support contractors, researchers, and pilot test or demonstration sites. Implementation activities should be evaluated on a regular basis through the use of appropriate quantitative and qualitative approaches.

Recommendation 3: Stable and predictable funding should be provided over several years to support SHRP 2 implementation activities. Total funding for the first 6 years of the implementation program is estimated at $400 million. The need for additional funding thereafter should be assessed at the appropriate time. Implementation planning and budgeting should take into account that several SHRP 2 products, especially the safety database, will require long-term support that will extend beyond the initial 6-year period.

Effective implementation will require the ability to plan several years of effort with a predictable funding flow; ideally, funding should be authorized to be "available until expended." The funding recommended for SHRP 2 implementation is intended to be over and above the usual level of funding for ongoing research and technology activities at FHWA and NHTSA to ensure that the implementation program does not have a negative impact on other much-needed activities of these agencies. NHTSA's provision of long-term stewardship for the safety database should be supported by funding provided by FHWA from the overall SHRP 2 budget. Products requiring long-term stewardship are difficult to maintain in the highly decentralized highway community, and they require special attention to ensure that the

public investment made in their development is allowed to fulfill its promise. These products all involve computer hardware or software and potentially large amounts of data (especially the safety database). Stable, predictable funding is required so they can be updated and maintained—for example, through periodic hardware or software upgrades that are too expensive to be sustained by individual projects. FHWA and NHTSA should perform a thorough study of the most effective means of providing long-term administrative and technical support for these products. The study should include investigation of various approaches, such as centralization versus decentralization; collocation with existing programs versus establishment of new entities; and use of the AASHTOWare, online hosted models, and cloud servers.

> **Recommendation 4:** A formal stakeholder advisory structure should be established to provide strategic guidance on program goals, priorities, and budget allocations, as well as technical advice. At a minimum, this advisory structure should include an executive-level oversight committee for the entire SHRP 2 implementation program and a second oversight committee focused exclusively on administration of the safety database.

Membership of the executive-level SHRP 2 implementation oversight committee should include the principal users of SHRP 2 products—state DOTs, local transportation agencies, metropolitan planning organizations, and appropriate private-sector and academic representatives—as well as experts on research implementation, IT, and knowledge management. The committee should be small enough to engage in efficient and effective decision making while including sufficiently broad stakeholder representation. The committee should meet at least twice a year. Its charge should include setting strategic priorities for the implementation program, reviewing and concurring with annual and multiyear program plans and budgets, monitoring progress on SHRP 2 implementation, and documenting results and lessons learned on which to base recommendations for future implementation efforts. In short, the SHRP 2 implementation oversight committee should be responsible for ensuring accountability in the SHRP 2 implementation program. The committee should report to Congress and the U.S. Department of Transportation annually.

It may be appropriate for the SHRP 2 implementation oversight committee to obtain additional specialized input from subcommittees or other groups that include technical experts, users of a particular group of research products, specialists in training and technology transfer, and other parties interested in or affected by SHRP 2 implementation. The number and nature of these other committees may evolve over time as the implementation program develops and progresses.

The size and unique features of the SHRP 2 safety database warrant a focused oversight group. A safety database oversight committee, under the general auspices of the SHRP 2 implementation oversight committee, should be established to provide oversight and advice on the long-term stewardship and use of the database. This committee should include highway safety researchers and practitioners from the public, private, and academic sectors, as well as experts in database management, security, and privacy issues. The committee should provide both policy and technical guidance to NHTSA and through NHTSA to any contractors the agency may engage to administer a safety data center. The committee's mission would be to ensure the widest possible access to the safety data, consistent with protection of the private or sensitive nature of the data, and to ensure that use of the data meets the highest scientific standards. NHTSA should determine the best way to provide institutional review board (IRB) oversight of the use of the data. The safety database oversight committee might serve as the IRB, might have an IRB subcommittee, or might cooperate with an existing IRB to ensure ethical use of the data.

Recommendation 5: Detailed implementation plans should be developed as soon as feasible to guide the implementation efforts.

The SHRP 2 research program is still at an early stage and does not include the charge to produce detailed implementation plans. As soon as implementation funding is made available, however, FHWA should develop detailed plans that include, at a minimum, the elements outlined in Chapter 7. These plans should be coordinated with the ongoing SHRP 2 research program and should be based on appropriate input from users and technical experts. The implementation plans should be living documents that are periodically updated and should be made publicly available.

APPENDIX A

SHRP 2 Committee Rosters

TRANSPORTATION RESEARCH BOARD OVERSIGHT COMMITTEE FOR THE STRATEGIC HIGHWAY RESEARCH PROGRAM 2

Chair

Allen D. Biehler, Secretary of Transportation, Pennsylvania Department of Transportation

Members

H. Norman Abramson, Executive Vice President (retired), Southwest Research Institute
Anne P. Canby, President, Surface Transportation Policy Partnership
Frank L. Danchetz, Vice President, ARCADIS G&M, Inc.
Dan Flowers, Assistant Chief Engineer, Operations, Arkansas State Highway and Transportation Department
Nicholas J. Garber, Henry L. Kinnier Professor, University of Virginia
Stanley Gee, Executive Deputy Commissioner, New York State Department of Transportation
Ronald F. Kirby, Director, Transportation Planning, Metropolitan Washington Council of Governments
Susan Martinovich, Director, Nevada Department of Transportation
John R. Njord, Executive Director, Utah Department of Transportation
Ananth Prasad, Chief Engineer, HNTB Corporation
Pete K. Rahn, Director, Missouri Department of Transportation
Kirk T. Steudle, Director, Michigan Department of Transportation
Richard E. Wagman, Chairman and CEO, G. A. & F. C. Wagman, Inc.

Ex Officio

James Ray, Acting Administrator, Federal Highway Administration
Nicole Nason, Administrator, National Highway Traffic Safety Administration

Andrew T. Horosko, Deputy Minister, Manitoba Infrastructure and Transportation
John C. Horsley, Executive Director, American Association of State Highway and Transportation Officials

Liaison
John Pearson, Program Director, Canadian Council of Deputy Ministers Responsible for Transportation and Highway Safety

SHRP 2 SAFETY TECHNICAL COORDINATING COMMITTEE

Chair
Forrest M. Council, Senior Research Scientist, Highway Safety Research Center, University of North Carolina

Members
James Bonneson, Research Engineer, Texas Transportation Institute, Texas A&M University
Richard K. Deering, Technical Fellow, General Motors Corporation
Leanna Depue, Director of Highway Safety Division, Missouri Department of Transportation
Joanne Harbluk, Human Factors Specialist, Transport Canada
James H. Hedlund, Principal, Highway Safety North, New York
Bruce Ibarguen, State Traffic Engineer, Maine Department of Transportation
Lawrence H. Orcutt, Research and Innovation Division Chief, California Department of Transportation
Robert Schomber, Regional Manager, Florida Power and Light Company
David Shinar, Professor, Ben Gurion University of the Negev
Alison Smiley, President, Human Factors North, Inc.
Thomas M. Welch, State Transportation Safety Engineer, Iowa Department of Transportation
Terecia W. Wilson, Director of Safety, South Carolina Department of Transportation

Liaisons

Michael Cammisa, Director, Safety, Association of International Automobile Manufactures, Inc.

Richard Compton, Director, Office of Behavioral Safety Research, National Highway Traffic Safety Administration

Michael Griffith, Director, Office of Research and Analysis, Federal Motor Carrier Safety Administration

Michael Halladay, Director, Office of Safety Integration, Federal Highway Administration

Ken F. Kobetsky, Program Director for Engineering, American Association of State Highway and Transportation Officials

Michael Perel, Chief, Human Factors/Engineering Integration Division, National Highway Traffic Safety Administration

Kent Speiran, Manager, Road Safety, Nova Scotia Department of Transportation and Infrastructure Renewal

Michael F. Trentacoste, Director of Safety, Research and Development, Federal Highway Administration

Fred Wegman, SWOV Institute for Road Safety Research, Netherlands

Vann Wilber, Director, Vehicle Safety and Harmonization, Alliance of Automobile Manufacturers

SHRP 2 RENEWAL TECHNICAL COORDINATING COMMITTEE

Chair

Randell H. Iwasaki, Chief Deputy Director, California Department of Transportation

Members

Daniel D'Angelo, Director and Deputy Chief Engineer, Office of Design, New York State Department of Transportation

Thomas E. Baker, State Materials Engineer, Washington State Department of Transportation

Thomas Callow, Senior Executive Assistant to the City Manager, City of Phoenix

Steven D. DeWitt, Chief Engineer, North Carolina Turnpike Authority

Alan D. Fisher, Manager, Construction Structures Group, Cianbro Corporation
Michael Hemmingsen, Davison Transportation Service Center Manager, Michigan Department of Transportation
Dennis M. LaBelle, Director of Utilities, M and T Consultants, Inc.
William N. Nickas, Principal Bridge Engineer, Corven Engineering, Inc.
Mary Lou Ralls, Principal, Ralls Newman, LLC
John J. Robinson, Jr., Assistant Chief Counsel, Pennsylvania Department of Transportation
Michael Ryan, Vice President, Michael Baker Jr., Inc.
Cliff J. Schexnayder, Eminent Scholar Emeritus, Arizona State University
Ronald A. Sines, Director, QC/QA Operations, P. J. Keating Company
Doug Urbick, President, A. Teichert and Son, Inc.
Thomas R. Warne, President, Tom Warne and Associates, LLC

Liaisons

Steve Gaj, Leader, System Management and Monitoring Team, Federal Highway Administration
James T. McDonnell, Associate Program Director for Engineering, American Association of State Highway and Transportation Officials
Cheryl Richter, Technical Director, Pavement R&D, Federal Highway Administration
Lance Vigfusson, Assistant Deputy Minister of Engineering and Operations, Manitoba Infrastructure and Transportation

SHRP 2 RELIABILITY TECHNICAL COORDINATING COMMITTEE

Chair

John F. Conrad, CH2M Hill

Members

Stephen P. Austin, Project Manager, Cumberland Valley Volunteer Firemen's Association
Malcolm E. Baird, Director, Vanderbilt University
Kevin W. Burch, President, Jet Express, Inc.

Henry DeVries, Operations Program Coordinator, I-95 Corridor Coalition/ New York State Police
Lily Elefteriadou, Director and Associate Professor, University of Florida
Lap Thong Hoang, Director, Traffic Engineering and Operations, Florida Department of Transportation
Patricia S. Hu, Director, Center for Transportation Analysis, Oak Ridge National Laboratory
Sarath C. Joshua, ITS and Safety Program Manager, Maricopa Association of Governments
Pat Kerins, Chief of Security, Del Mar Fairgrounds and Race Tracks
Mark F. Muriello, Assistant Director, Tunnels, Bridges, and Terminals, Port Authority of New York and New Jersey
Richard J. Nelson, Assistant Director, Operations, Nevada Department of Transportation
Constance S. Sorrell, Chief of Systems Operations, Virginia Department of Transportation
John P. Wolf, Assistant Division Chief, Traffic Operations, California Department of Transportation
Margot Yapp, Vice President, Nichols Consulting Engineers, Chtd.

Liaisons

Andrew Beal, Manager, Traffic Office, Ontario Ministry of Transportation
Mark S. Bush, Program Manager for Transportation Operations, American Association of State Highway and Transportation Officials
Raj Ghaman, Team Leader, Office of Operations R&D, Federal Highway Administration
Regina McElroy, Director, Office of Transportation Management, Federal Highway Administration

SHRP 2 CAPACITY TECHNICAL COORDINATING COMMITTEE

Cochairs

Neil J. Pedersen, Administrator, Maryland State Highway Administration
Mary Lynn Tischer, Director, Multimodal Transportation Planning Office, Virginia Department of Transportation

Members

Mark Van Port Fleet, Engineer of Design, Michigan Department of Transportation

Kris Hoellen, Director, Conservation Leadership Network, Conservation Fund

Charles E. Howard, Jr., Director, Transportation Planning, Puget Sound Regional Council

Carolyn H. Ismart, Florida

T. Keith Lawton, Keith Lawton Consulting, Inc.

Catherine L. Ross, Director and Harry West Professor, Center for Quality Growth and Regional Development, Georgia Institute of Technology

Joseph L. Schofer, Professor of Civil Engineering and Environmental Engineering and Associate Dean, McCormick School of Engineering and Applied Science, Northwestern University

Brian J. Smith, Director, Strategic Planning and Programming, Washington State Department of Transportation

John V. Thomas, Office of Policy, Economics, and Innovation, Environmental Protection Agency

Gary Toth, Project for Public Spaces

Jeff Welch, Director, Knoxville Regional Transportation Planning Organization

Liaisons

Robert A. Ferlis, Technical Director, Office of Operations R&D, Federal Highway Administration

Janet P. Oakley, Director, Policy and Government Relations, American Association of State Highway and Transportation Officials

Thérèse Trépanier, Direction de la recherche et de l'environnement, Ministère des Transports du Québec

Felicia B. Young, Research and Financial Service Team Leader, Federal Highway Administration

APPENDIX B

SHRP 2 Projects and Expected Products

TABLE B-1 SAFETY RESEARCH THEMES, PROJECTS, AND PRODUCTS

Theme	Safety Research Projects	Expected Products
Study design and field data collection	S05: Design of the In-Vehicle Driving Behavior and Crash Risk Study	Field study design Specifications and prototypes for data acquisition system Field study management plan
	S06: Technical Coordination and Independent Quality Assurance for Field Study	Field study procedures Integrated database
	S07: In-Vehicle Driving Behavior Field Study	Site-specific data
	S12: Data Acquisition System	Not applicable
Roadway data	S03: Roadway Measurement System Evaluation	Methodology for evaluation of mobile measurement systems collecting data related to safety analysis State-of-the-practice report for mobile collection of safety-related data elements
	S04: Acquisition of Roadway Information	Geographic information system database of roadway and roadside characteristics and features for selected segments of roads in geographic areas used for field study
Analysis	S01: Development of Analysis Methods Using Recent Data	Analysis methods
	S02: Integration Methods and Development of Analysis Plan	Analysis plan
	S08: Analysis of In-Vehicle Field Study Data and Countermeasure Implications	Analysis of selected safety questions
Site-based study	S09: Site-Based Video System Design and Development	Site-based video system

TABLE B-2 RENEWAL: RELATIONSHIP OF RESEARCH PRODUCTS TO RESEARCH OBJECTIVES, TACTICS, AND PROJECTS

Objective	Tactic	Renewal Research Projects	Expected Products
Rapid approaches	1. Perform faster in situ construction	R01: Encouraging Innovation in Locating and Characterizing Underground Utilities	State-of-the-art manual Electronic database of state-of-the-art technologies Long-term research and development plan New tools and training materials
		R02: Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform	Material/Technology Selection Catalog Guidelines Performance-related specifications Construction inspection certification programs Design procedures
	2. Minimize field fabrication	R04: Innovative Bridge Designs for Rapid Renewal	Design specifications Construction specifications Contracting tools Training materials
		R05: Modular Pavement Technology	Modular pavement feasibility study Design procedures Guidelines and model specifications Long-term evaluation plan
	3. Perform faster inspection and monitoring	R06: A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection	Test procedures Proof of concept of emerging techniques Training materials
	4. Facilitate innovative and equitable contracting environment	R07: Performance Specifications for Rapid Highway Renewal	Guidelines Model specifications
		R09: Risk Manual for Rapid Renewal Contracts	Guidelines for implementation Training materials

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TABLE B-2 *(continued)* **RENEWAL: RELATIONSHIP OF RESEARCH PRODUCTS TO RESEARCH OBJECTIVES, TACTICS, AND PROJECTS**

Objective	Tactic	Renewal Research Projects	Expected Products
Minimize disruption	5. Improve customer relations	R15: Strategies for Integrating Utility and Transportation Agency Priorities in Renewal Projects	Best-practices manual Testing and evaluation plan Recommended institutional and policy changes Model agreements for cooperation
		R16: Railroad-DOT Institutional Mitigation Strategies	Best-practices document Model agreements Streamlined permitting procedures Recommended specification, institutional, and policy changes for implementation
Produce long-lasting facilities	6. Design and construct low-maintenance facilities	R19-A: Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems, and Components	Load and resistance factor design and construction specifications Standard plans Detailed design examples
		R19-B: Bridges for Service Life Beyond 100 Years: Service Limit State Design	Load and resistance factor design and construction specifications Standard plans Detailed design examples
		R21: Composite Pavement Systems	Guidelines Design, materials, and construction manuals Training materials
		R23: Using Existing Pavement in Place and Achieving Long Life	State-of-the-art report Design guides Construction procedures and specifications
	7. Preserve facility life	R26: Preservation Approaches for High Traffic Volume Roadways	Guidelines Methodology and supporting data for life-cycle considerations Research plan

TABLE B-3 RELIABILITY RESEARCH THEMES, PROJECTS, AND PRODUCTS

Theme	Reliability Research Projects	Expected Products
1. Data, metrics, analysis, and decision support	L02: Establishing Monitoring Programs for Travel Time Reliability	Guidebook for establishing travel time monitoring programs Report on traffic detector technologies, conversion of traffic recorders to provide real-time information, and integration of various data on nonrecurring congestion
	L03: Analytical Procedures for Determining the Impacts of Reliability Improvement Strategies	Report on technical relationships between mitigation measures and performance measures Report on pilot studies of field data collection to support assessment of analytical procedures
	L04: Incorporating Reliability Performance Measures into Planning and Operations Modeling Tools	Report on how planning and traffic simulation models can be modified to incorporate reliability performance measures Report on proof of concept of the modifications Guidelines for incorporation
	L13: Developing the Requirements for Designing and Implementing a System for Archiving and Disseminating Data from SHRP 2 Reliability and Related Studies	Guidelines for a reliability data archiving and dissemination system using web-based mechanisms An archival system that is documented, tested, and populated for use
2. Institutional change, human behavior, and resource needs	L01: Integrating Business Processes to Improve Reliability	Report on successful examples of integration of business processes to improve travel time reliability Guidelines for agencies for implementing successful business practices to improve travel time reliability
	L06: Institutional Architectures to Advance Operational Strategies	Workshop report on key institutional architecture issues Report on successful practices recently instituted Guidebook for agencies for changing institutional architectures in support of improved operational strategies

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TABLE B-3 *(continued)* **RELIABILITY RESEARCH THEMES, PROJECTS, AND PRODUCTS**

Theme	Reliability Research Projects	Expected Products
	L10: Using In-Vehicle Video Data to Explore How to Modify Driver Behavior that Causes Nonrecurring Congestion	Report on the feasibility of using in-vehicle video data to support investigations aimed at modifying congestion-causing behavior Report on studies using in-vehicle video data to investigate means of modifying congestion-causing behavior
	L12: Training and Certification of Traffic Incident Responders	Checklist of responder actions and identification of core competencies for responders Curriculum and instruction outline for key responder types Recommended framework for responder certification Report on pilot study and evaluation of certification process
	L14: Effectiveness of Different Approaches to Disseminating Traveler Information on Travel Time Reliability	Identification of traveler information methods Assessment of how improved travel information systems would affect road user behavior Report on alternative mechanisms for agencies to improve traveler information services
3. Incorporating reliability into planning, programming, and design	L05: Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes	Procedures for linking countermeasures to reliability performance measures Report on analysis of trade-offs in capital versus operating expenditures resulting from using mobility and reliability performance measures in the programming process Report on analysis of how using reliability performance measures fits into the short-term programming process

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Theme	Reliability Research Projects	Expected Products
	L07: Evaluation of Costs and Effectiveness of Highway Design Features to Improve Travel Time Reliability	Report on design practices aimed at improving travel time reliability Assessment of the cost-effectiveness of using design practices to improve travel time reliability Guidebook of design practices that can improve travel time reliability
	L08: Incorporation of Nonrecurrent Congestion Factors into the Highway Capacity Manual Methods	Methodology for predicting the probability of occurrence of nonrecurring incidents in varying conditions Methodology for predicting impacts on speed and delay Methodology for predicting the effectiveness of design and management strategies for reducing nonrecurring congestion
	L09: Incorporation of Nonrecurrent Congestion Factors into the AASHTO *Policy on Geometric Design*	Report on how to incorporate factors in nonrecurring congestion into the American Association of State Highway and Transportation Officials design guide
4. Future needs and opportunities to improve travel time reliability	L11: Evaluating Alternative Operations Strategies	Report on the requirements of road users for travel time reliability and the ability of agencies to meet these requirements Report on suggested operations strategies for improving travel time reliability
	L15: Reliability Innovations Deserving Exploratory Analysis	Reports from several projects aimed at identifying and testing innovative concepts to improve travel time reliability

TABLE B-4 CAPACITY RESEARCH THEMES, PROJECTS, AND PRODUCTS

Theme	Capacity Research Projects	Expected Products
1. Elements of collaborative decision making	C01: A Framework for Collaborative Decision Making on Additions to Highway Capacity	Collaborative Decision-Making Framework built around 30 key decision points Twenty-five case studies Tabletop vetting exercises
	C07: Integrating SHRP 2 Products into the Collaborative Decision-Making Framework	Integration of all products into a modular, flexible, usable product
	C02: A Systems-Based Performance Measurement Framework for Highway Capacity Decision Making	Knowledge-based web resource Library of measures and data needs Guidelines for selecting measures Examples of good practice
	C08: Linking Community Visions and Highway Capacity Planning	Guidelines for incorporating community visioning into highway capacity decisions and ensuring that they are followed through to project development
	C09: Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process	Guidelines for considering greenhouse gas emissions in the various key decision points in the decision process
	C12: The Effect of Public–Private Partnerships and Nontraditional Procurement Processes on Highway Planning, Environmental Review, and Collaborative Decision Making	Good practices for adapting to public–private partnerships and design–build procurements
	C13: Integrating Full Cost and Fiscal Impact Analysis into Collaborative Decision Making	Guidelines for full cost analysis and allocation of present and future costs to jurisdictions
	C14: Developing a Multiagency Change Management Framework	A guide to the theory and practice of changing one's own agency and others, organized around key decision points in the decision process
	C15: Integrating Freight Considerations into the Collaborative Decision-Making Process	Good practices for considering freight transport in the collaborative decision-making process

(continued)

Theme	Capacity Research Projects	Expected Products
2. Ecological approach to surface environmental protection	C06A: Integration of Conservation, Highway Planning, and Environmental Permitting Using an Outcome-Based, Ecosystem Approach	Methods and procedures for interagency environmental cooperation at all key decision points in the highway delivery process Science-based system of multi-purpose credits for habitats, wetlands, and endangered species
	C06B: Development of an Ecological Assessment Process and Credits System for Enhancements to Highway Capacity	A business model for an ecological approach Model programmatic agreements Guidelines document to assist in adopting an ecological approach
3. Improved tools for analysis of travel behavior	C10: Partnership to Develop an Integrated, Advanced Travel Demand Model and Fine-Grained, Time-Sensitive Network	SHRP 2 partnership with one or two metropolitan planning organizations or departments of transportation Bringing an advanced model set and time-sensitive network online Testing the ability of the integrated model set to estimate time and route shifts in response to tolls or congestion (C04 products) Testing the ability to deliver fine-grained inputs to air quality models (C09) Testing the ability to estimate effects of operations, design, and technology improvements (C05) Having a catalytic effect on accelerated adoption of these techniques by others
	C04: Improved understanding of How Congestion and Pricing Affect Travel Demand	Mathematical representations of how motorists react to highway congestion and pricing Product packaged for use in models Testing of product in C10 partnership

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TABLE B-4 *(continued)* **CAPACITY RESEARCH THEMES, PROJECTS, AND PRODUCTS**

Theme	Capacity Research Projects	Expected Products
	C05: Understanding the Contribution of Operations, Technology, and Design to Meeting Highway Capacity Needs	Tools to quantify network-level capacity benefits, individually and in combination, of operations, design, and technology improvements Guidelines for using results in planning networks to reflect sustained service rates
	C16: The Effect of Smart Growth Policies on Travel Demand	Analysis of the effect of smart growth policies on peak-period travel demand and methods for analysis that may entail the tools of the C10 partnership
4. Economic impacts of highway investment	C03: Interactions Between Transportation Capacity, Economic Systems, and Land Use and Integrating Economic Considerations into Project Development	Sixty case studies distributed across various highway types, degrees of urbanization, and geographic regions Case-based reasoning tools to use the case studies Practitioners' handbook
	C11: Development of Improved Economic Analysis Tools Based on Recommendations from Project C03	Techniques for integrating data-based analytical tools with case-based tools

Study Committee Biographical Information

Kirk T. Steudle, *Chair*, was appointed Director of the Michigan Department of Transportation (MDOT) in March 2006. Since joining MDOT in 1987, he has served in a number of posts, including Chief Deputy Director, engaged in all aspects of transportation in the state of Michigan; Bay Region Engineer, responsible for the administration and delivery of all transportation programs and services for the 13-county region surrounding the Saginaw Bay area; and Metro Detroit Deputy Region Engineer. Mr. Steudle represents MDOT on the Michigan Transportation Asset Management Council and chairs the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Asset Management and Standing Committee on Highway Traffic Safety. In 2004 he was a member of the National Asset Management Delegation, conducting a Transportation Asset Management Seminar in Riga, Latvia, for the countries of Estonia, Latvia, and Lithuania. In 2005 he participated in the Federal Highway Administration (FHWA)–AASHTO International Scan with regard to Asset Management in Australia, New Zealand, Canada, and England. Mr. Steudle currently plays a leadership role in the development of vehicle infrastructure integration, sits on the Board of Directors of the Intelligent Transportation Society of America (ITS America), and is a member of the AASHTO Executive Committee and the Strategic Highway Research Program (SHRP) 2 Oversight Committee.

Forrest M. Council is a Senior Research Scientist at the University of North Carolina Highway Safety Research Center (HSRC), where he served as Director from 1993 to 1999. He is also a Senior Research Consultant to VHB, a transportation engineering firm in Vienna, Virginia. In his 35 years at HSRC, Dr. Council directed more than 20 projects and authored more than

80 articles and reports. His research has ranged from studies of motor vehicle injury for specific populations (children, beginning drivers, seat-belted occupants) to projects aimed at identifying and strengthening research methodologies in the roadway safety field. Over the past 15 years, he has directed the planning, development, and implementation of FHWA's Highway Safety Information System, a database that contains crash, roadway inventory, and traffic volume data for nine states. Dr. Council chaired the National Research Council's Committee for Review of the Federal Motor Carrier Safety Administration's Large Truck Crash Causation Study and served on the Research and Technology Coordinating Committee and the Committee for Guidance on Setting and Enforcing Speed Limits. He has also served on several Transportation Research Board (TRB) standing committees and National Cooperative Highway Research Program (NCHRP) project panels. He earned his BS, MS, and PhD from North Carolina State University, all in civil engineering. Dr. Council is Chair of the SHRP 2 Safety Technical Coordinating Committee.

C. Douglass Couto is Director of Transportation for State and Local Government at Citrix Systems, Inc. Previously he held various public-sector positions. He was Information Officer in the Michigan Department of Information Technology, providing support for major enterprise systems and MDOT. He also was Chief Information Officer for MDOT after serving as Chief Information Officer for the state of Iowa. Mr. Couto spent 22 years in various information management positions while on active duty with the United States Air Force, including Director of Information Management for the Air Force Intelligence Agency in San Antonio, Texas. He holds a bachelor's degree from the University of Iowa and master's degrees in business administration and public administration from the George Washington University. He is also a graduate of the National Defense University. He chairs TRB's Information Systems and Technology Committee.

Thomas B. Deen (NAE) is a transportation consultant and served as Executive Director of TRB from 1980 to 1994. He is former Chairman and President of PRC-Voorhees, a transportation engineering and planning consulting firm, where he was in charge of major urban highway and rail transit projects, both in this country and abroad. Mr. Deen served as Chair of the national inter-

agency committee that prepared the strategic plan for America's development of intelligent transportation systems. In recent years, he has been appointed chair of several blue ribbon Maryland state committees investigating significant rail and road projects in the state. He also serves on an advisory board for the U.S. Department of Transportation's Bureau of Transportation Statistics. Mr. Deen holds a bachelor's degree from the University of Kentucky and a certificate from Yale University's Bureau of Highway Traffic.

Joel P. Ettinger is currently Executive Director of the New York Metropolitan Transportation Council, the transportation planning organization for the New York metropolitan region. Before that appointment, he was Regional Administrator for the Federal Transit Administration in Chicago, with responsibility for federal transit activities in the states of Illinois, Indiana, Minnesota, Michigan, Ohio, and Wisconsin. Between 1976 and 1981, he served as Chief of the Analysis Division in the Headquarters Office of the Urban Mass Transportation Administration (UMTA), where he was responsible for managing the alternatives analysis program for major urban mass transit investments. Mr. Ettinger joined the federal government in 1968 as a highway engineer trainee in FHWA. He completed an 18-month training program that included assignments at FHWA regional and division offices and at the Puget Sound Governmental Conference, the metropolitan planning organization in Seattle, Washington. He joined UMTA in 1971 as a Transportation Planner in the Headquarters Office and helped administer UMTA's planning program for urban areas and states. He received a bachelor's degree in civil engineering from the City College of New York and a master of science degree in transportation planning from Northwestern University.

David R. Gehr is Senior Vice President, Highway Markets, for Parsons Brinckerhoff (PB), providing marketing guidance and technical expertise to PB's highway-related pursuits and ongoing projects and developing strategies for growth in the firm's highway portfolio. Previously Mr. Gehr worked for the Virginia Department of Transportation (VDOT) from 1971 to 1999. He held several senior executive positions at VDOT, including District Engineer, Director of Operations, Chief Engineer, and Assistant Commissioner for Operations. In 1994 he was appointed

Commonwealth Transportation Commissioner for VDOT. Before joining VDOT Mr. Gehr served as a commissioned officer in the United States Army. He has served on the Board of Directors of ITS America and as Chair of the I-95 Corridor Coalition. He received a BS degree in civil engineering from the Virginia Military Institute and has done graduate work in transportation planning and in systems engineering. He was a member of the Committee for a Study for a Future Strategic Highway Research Program.

Robert C. Johns is Director of the Center for Transportation Studies at the University of Minnesota, which carries out research programs, provides interdisciplinary education programs for transportation students, and conducts training and outreach programs for transportation professionals and policy leaders. Before joining the university in 1988, he worked for the Metropolitan Council of the Twin Cities Area, the Minnesota Department of Transportation, and the Atchison, Topeka and Santa Fe Railway. He is Chair of the TRB Technical Activities Council, which consists of eleven group chairs who oversee the research and outreach activities of 200 technical committees. He was formerly Chair of the TRB Policy and Organization Group, Chair of the Management and Leadership Section, and Chair of the Committee on Strategic Management. He has also chaired committees for ITS America and the Urban and Regional Information Systems Association. He serves on the Minnesota Guidestar Board of Directors and the Minnesota Freight Advisory Committee. Mr. Johns holds a bachelor's degree from Iowa State University and an MBA and a master's degree in English from the University of Iowa.

Robert C. Lange is Executive Director for Vehicle Structure and Safety Integration at General Motors (GM) Corporation, where he focuses on the in-service safety performance of GM motor vehicle products and real-world customers' experiences with those products. He joined GM in 1994 following a 12-year career with Failure Analysis Associated (FaAA), an engineering consulting firm, where he was involved with research and consulting activities for motor vehicle safety. Before joining FaAA, he held a variety of design engineering positions at Ford Motor Company. Mr. Lange has written extensively about motor vehicle safety topics, including the design

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Ananth K. Prasad is Vice President for HNTB Corporation and currently serves as Market Sector Leader for the U.S. Department of Transportation. He is responsible for coordinating HNTB's service offerings to departments of transportation throughout the southeastern United States. Previously, Mr. Prasad worked for the Florida Department of Transportation (FDOT) from 1991 to 2008 and was FDOT's Chief Engineer for 3 years before joining HNTB. Mr. Prasad joined FDOT as a Scheduling Engineer and has been Construction Project Manager, Assistant District Construction Engineer, Resident Engineer, and Director of Construction. He currently serves on many TRB committees, was a member of the SHRP 2 Oversight Committee, and chaired AASHTO's Technical Implementation Group. Mr. Prasad holds a bachelor of science degree in civil engineering and a master of engineering degree in civil engineering; he is a registered professional engineer in the state of Florida.

Mary Lou Ralls is Principal of Ralls Newman, LLC, in Austin, Texas, a firm specializing in the advancement of structural engineering technologies, including accelerated construction. Before becoming an independent consultant in late 2004, Ms. Ralls was with the Texas Department of Transportation (TxDOT) for 20 years, serving for the last 5 years as State Bridge Engineer and Director of the Bridge Division. While at TxDOT, she was a member of the AASHTO Highway Subcommittee on Bridges and Structures and was Chair of the Technical Committee for Security and Vice Chair of the Technical Committee for Research. She also was a member of the AASHTO Task Force on Transportation Security. She holds bachelor's and master's degrees in civil engineering from the University of Texas at Austin and is a licensed professional engineer. She serves as Chair of the TRB Design and Construction Group. Ms. Ralls is also a member of several NCHRP panels on transportation structures and security. She is a member of the SHRP 2 Technical Coordinating Committee for Renewal.

Mary Lynn Tischer is Director of the Multimodal Transportation Planning Office and Federal Intergovernmental Transportation Liaison for VDOT. The Multimodal Transportation Planning Office was created to facilitate implementation of VTrans2025, Virginia's statewide multimodal transportation plan. As Federal Intergovernmental Transportation Liaison for VDOT, Dr. Tischer leads the development of initiatives at the federal level with regard to the commonwealth's transportation system. From 2002 until 2005, she was a Special Assistant to the Governor and the Secretary of Transportation, working with the Virginia legislative delegation and others to secure federal legislation favorable to the state. She has held administrative posts in the U.S. Department of Transportation, FHWA, the Arizona Department of Transportation, and the Volpe National Transportation Systems Center. From 1989 to 1997, Dr. Tischer served VDOT as Director of the Office of Policy Analysis, Evaluation, and Intergovernmental Relations. She holds a bachelor's degree from Rosemont College, a master's degree from American University, and a PhD in political science from the University of Maryland. Dr. Tischer has served on several AASHTO committees, including the Task Force on Federal Reauthorization, the Standing Committee on Planning, the Task Force on Economic Development, and the Standing Committee on Highway Transport. She was a member of the

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John P. Wolf is Assistant Division Chief in Traffic Operations for Transportation Planning and System Management for the California Department of Transportation (Caltrans). He has held numerous positions at Caltrans, where he helped develop transportation system performance measures for the California Transportation Plan, managed the Traffic Operations Strategies, developed the Transportation Management System Master Plan, and worked on emerging Corridor Mobility Management strategies. Each of these efforts promoted performance measurement and the need for transportation system providers to work cooperatively to improve transportation system performance for California. He also led the development of the Freeway Performance Measurement System (PeMS) through the University of California, Berkeley, as a research project. PeMS will be mainstreamed as a Caltrans system. Mr. Wolf holds a bachelor's degree in political science from the University of Scranton and a master's degree in city and regional planning from the Catholic University of America. He is a member of the SHRP 2 Technical Coordinating Committee for Reliability.

Implementing the Results of the Second Strategic Highway Research Program

Saving Lives, Reducing Congestion, Improving Quality of Life

Developments in research and technology—such as advanced materials, communications technology, new data collection technologies, and human factors science—offer an opportunity to achieve breakthrough advances for the nation's 4-million-mile highway system. The second Strategic Highway Research Program (SHRP 2) applies these developments to research on promising approaches to increasing safety, reducing congestion, minimizing disruption when roads are rehabilitated, and providing new highway capacity that will enhance both the human and the natural environments. The products of SHRP 2 research, if widely implemented, could change the way decisions are made by transportation agencies, the methods they use to build and renew highways, and the services they offer to highway users.

The committee that authored this report believes that widespread implementation of products developed from SHRP 2 research is critical to address the roadway safety, renewal, reliability, and capacity issues that threaten to impair the nation's economy and quality of life. To accomplish this, an implementation program should be established; the Federal Highway Administration, in partnership with others, should serve as the principal implementation agent; stable and predictable funding of $400 million over 6 years should be provided for implementation activities; a formal stakeholder advisory structure should be established; and detailed implementation plans should be developed as soon as feasible to guide the implementation efforts.

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