SPECIAL REPORT 256

Managing Technology Transfer

A Strategy for the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD

NATIONAL RESEARCH COUNCIL

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Managing Technology Transfer

A Strategy for the Federal Highway Administration

Research and Technology
Coordinating Committee

TRANSPORTATION RESEARCH BOARD
National Research Council

NATIONAL ACADEMY PRESS
WASHINGTON, D.C. 1999

Transportation Research Board Special Report 256

Subscriber Category
IA planning and administration

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Printed in the United States of America.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

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.

This report was sponsored by the Federal Highway Administration, U.S. Department of Transportation.

Cover design by Tamara Lee

Library of Congress Cataloging-in-Publication Data

Managing technology transfer: a strategy for the Federal Highway Administration / Research and Technology Coordinating Committee.

99 pp., 23x15 cm.—(Special report - Transportation Research Board, National Research Council; 256)

ISBN 0-309-7102-X

I. Highway engineering—Technological innovations—United States. 2. Technology transfer—United States—Management. 3. Transportation equipment industry—Technological innovations—United States. 4. Road construction industry—Technological innovations—United States. I. National Research Council (U.S.). Transportation Research Board. Research and Technology Coordinating Committee. II. Special Report (National Research Council (U.S.). Transportation Research Board); 256.

TE153.M36 1999 99-046600
625.7'0973—dc21 CIP

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Preface

The Research and Technology Coordinating Committee (RTCC), a special committee convened by the Transportation Research Board (TRB) of the National Research Council and funded by the Federal Highway Administration (FHWA), provides continuing guidance to FHWA on highway research and technology opportunities and priorities. Since 1992 the committee has addressed a variety of topics, some at the request of FHWA and others selected by the committee in consultation with the agency. This report addresses a subject that has been of interest to the committee for some time: how FHWA selects research products for technology transfer and transfers those products to the highway industry, in particular the state and local agencies that own, operate, and maintain the nation's highways.

During a review of the research facilities and activities at FHWA's Turner-Fairbank Highway Research Center (TFHRC) in October 1997, the committee expressed interest in learning more about how FHWA's Office of Technology Applications (OTA) selected research products for its technology transfer program and how it delivered these products to end-users. This interest meshed with an earlier FHWA suggestion that the RTCC help OTA identify the customers for the research products promoted by the office. After the meeting at TFHRC, Robert Betsold, then FHWA's Associate Administrator for Research and Development, and Dennis Judyki, then FHWA's Associate Administrator for Safety and Systems Applications (where OTA was located within FHWA) and currently Director of the Office of

Research, Technology, and Development, encouraged the RTCC to review FHWA's technology transfer activities and make suggestions for improving its technology delivery system. Such a study was also supported by Joseph Toole, Director of OTA, who noted FHWA's need to develop performance measures for its technology transfer activities in response to the requirements of the 1993 Government Performance and Results Act (GPRA).[1]

As a result of these and other discussions, the RTCC decided to examine technology transfer within OTA. The committee's purpose was to address how FHWA can improve its technology transfer program efforts to accelerate innovation in the highway sector.[2] The committee defined its scope to comprise three topics: (1) how OTA identified and selected technologies for transfer, (2) how it set program priorities and made resource allocation decisions, and (3) how it measured program success.

The RTCC initiated its study by forming a task force under the direction of Irwin Feller, Director of the Institute for Policy Research and Evaluation, and Professor of Economics, Pennsylvania State University. Other task force members included current RTCC members Forrest Council, Frank Danchetz, and Nancy Fitzroy and former RTCC member Neville Parker. At RTCC meetings in March and June 1998, FHWA staff briefed the committee on the agency's organization and methods for technology transfer. In August 1998 the task force met with FHWA staff to examine several recent technology transfer initiatives and to review alternative technology transfer strategies. The committee also examined material prepared by TRB staff that reviewed the literature on technology transfer and described specific case studies of FHWA technology transfer activity.

During the study, two events took place that affected the formulation of the committee's recommendations. First, passage of the Transportation Equity Act for the 21st Century (TEA-21) in June 1998 greatly reduced FHWA's technology transfer budget.[3] Although the administration requested more than $100 million annually for FHWA technology transfer and related activities, Congress provided about $40 million annually, the majority of which was earmarked for specific activities or designated for particular recipients.

Second, effective October 1998, FHWA reorganized its headquarters office and eliminated OTA. The reorganization created five new core business units and eight service business units in a matrix organization.[4] It distributed responsibility for FHWA technology transfer among the core business units and the new service business unit for research, development, and technology. In addition, as part of its overall reorganization, FHWA closed its nine regional offices and established four technical resource centers to support the state-level division offices in their primary role of program delivery.[5] FHWA reorganized to emphasize technology delivery to state and local highway agencies at a time when these agencies need new technologies to address problems caused by heavy use, congestion, and deterioration. With no new major construction programs and fewer restrictions on federal highway funds, FHWA seeks to accomplish technology delivery through leadership and guidance in cooperation with state and local highway agencies.

As a result of the reorganization, the committee's recommendations, while always aimed at FHWA's technology transfer efforts and the acceleration of innovation, now apply to the five core business units and the research, development, and technology service business unit, rather than to OTA. The recommendations are based on a review of the relevant literature, presentations by FHWA staff, and other information gathered by the committee and staff, as well as the collective judgment of the committee members. The committee had hoped to be able to review detailed empirical information on a variety of OTA's specific technology transfer activities, including resources expended for individual initiatives and implementation results. OTA had not collected such detailed information, however, and was therefore unable to provide it. OTA staff did provide anecdotal information in a number of presentations.

The recommendations in this report are aimed at the establishment of a specific strategy for FHWA's technology transfer activities.[6] The proposed strategy addresses programmatic issues related to identifying, selecting, and prioritizing technologies for transfer; making resource allocations; and measuring program success. The recommendations also address what the committee sees as a management gap created by FHWA's recent reorganization, which the committee believes could

have an impact on the overall effectiveness of agencywide technology transfer efforts.

The principal audience for the report consists of top-level management at FHWA responsible for technology transfer. The intended audience also includes FHWA's primary customers—the state and local highway agencies—along with highway contractors, materials suppliers, and other components of the highway industry.

The committee would like to recognize the FHWA staff members who provided valuable information and background material. Joseph Toole, Michael Halladay, and Byron Lord, formerly of OTA, were particularly helpful in preparing material for the committee and participating in several discussions about specific aspects of OTA's activities. In addition, Anna Bennett, Jeffrey Lindley, John Hooks, and John McCracken of FHWA and William Carr of the Washington Department of Transportation made presentations to the committee.

The study was performed under the overall supervision of Stephen R. Godwin, Director of Studies and Information Services. Walter J. Diewald served as the project director. The committee also wishes to thank Suzanne Schneider, Assistant Executive Director of TRB, who managed the report review process. The report was edited by Rona Briere and prepared for publication under the supervision of Nancy A. Ackerman, Director of Reports and Editorial Services.

The report was 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 Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report: Gary R. Allen, Virginia Transportation Research Council; Randall Erickson, 3M Laboratories; Lester A. Hoel, University of Virginia; Damian J. Kulash, Eno Transportation Foundation, Inc.; John P. McTague, Montecito, California; and J. David Roessner, Georgia Institute of Technology. Although the individuals listed above have provided con-

structive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests solely with the authoring committee and the institution.

NOTES

1. GPRA requires federal agencies to set strategic goals and to use performance measures for management and budgeting.
2. As noted in the committee's initial report (TRB 1994) FHWA's major research functions and its technology transfer functions were separated organizationally and supported by individual budget accounts. This separation of functions led the RTCC to address technology transfer as it is practiced at FHWA.
3. TEA-21 authorizes highway, highway safety, transit, and other surface transportation programs for a 6-year period.
4. The five core business units address infrastructure, operations, planning and environment, motor carrier and highway safety, and federal lands highway. The eight service business units focus on policy; administration; research, development, and technology; professional development; corporate management; civil rights; public affairs; and legal counsel. Appendix A provides statements of the research and technology delivery functions for FHWA's core business units and the research, development, and technology service unit.
5. Each resource center serves a group of states within a geographical area, and each provides specific technical expertise on a limited set of topics. Technical expertise is shared among the resource centers and FHWA's state-level division offices as needed.
6. In its May 14, 1998, letter report to the FHWA Administrator, the RTCC noted the lack of a strategy for FHWA technology transfer activities. The committee suggested that "basing the activities of FHWA's Office of Technology Applications on a formal model of technology transfer—one grounded in empirical data and the experience of agency staff—can help avoid repeated use of the same methods because they 'usually work,' rather than changing or adapting methods as appropriate for particular circumstances. Such a model can also help an agency optimize the use of various methods, respond to unusual situations, and communicate better among the stakeholders involved in the technology transfer process."

REFERENCE

ABBREVIATION

TRB Transportation Research Board

TRB. 1994. *Special Report 244: Highway Research: Current Programs and Future Directions*. National Research Council, Washington, D.C.

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Executive Summary

Widespread implementation of technologies is an important outcome of research and development (R&D) programs, and technology transfer is therefore essential to the technology delivery mission of the Federal Highway Administration (FHWA). A previous report prepared by the Research and Technology Coordinating Committee (RTCC), a special committee convened by the Transportation Research Board (TRB) of the National Research Council and funded by FHWA, describes research, development, and technology transfer in the highway industry (TRB 1994). The report reviews the changing priorities of the nation's highway program and urges FHWA and state and local highway agencies to find ways to ensure that research products are implemented, recognizing that innovation does not occur unless new products, processes, and methods are put to use.

The committee uses the term *technology transfer* to describe a range of activities that involve researchers, technology users, and technology transfer specialists. These activities include (1) identifying innovative technologies from numerous sources, such as FHWA R&D programs, state highway agency research programs, university research, the National Cooperative Highway Research Program, foreign laboratories and research institutes, and other government agencies; (2) selecting and prioritizing technologies to be promoted to state and local highway agencies and the highway industry; (3) determining, developing, and applying effective technology transfer methods; and (4) continually modifying the technology transfer process in accordance with feed-

back on which technologies and which methods of technology transfer have been successful.[1]

Public agencies are particularly reliant on technology transfer programs for several reasons. The large volume of R&D under way and the dispersion of R&D agencies serve to deter many of these seeking useful information. Research reports are often highly technical, with little information to aid potential implementing agencies. And the information provided in professional and trade journals often lacks important technical details. Technology transfer programs can provide information at different levels of detail for different audiences, as well as technical assistance, user training, and financial support for implementation efforts.

KEY FINDINGS

Management responsibility for technology transfer activities has been neglected by FHWA in its reorganization plan.

Despite its stated mission of technology delivery, FHWA has underemphasized the importance of technology transfer management in its recent reorganization. As part of the reorganization, the Office of Technology Applications (OTA), until recently the focal point for FHWA's technology transfer activities, was eliminated. Technology transfer is now a staff function in each of FHWA's five new core business units and its research, development, and technology service unit [the Office of Research, Development, and Technology (ORDT)]. Although this arrangement can facilitate a closer connection between the individual business units and the potential users of technology, it also spreads FHWA's technology transfer expertise across many offices. The risk is that FHWA's technology transfer competence will be dissipated, and the advantages of locating the agency's technology transfer capability in a single management unit, such as ease of monitoring agencywide technology transfer activities and evaluating what does and does not work, will be lost. In addition, FHWA has not articulated how the flow of knowledge and information between researchers and technology transfer specialists in the five core business units, ORDT, the four resource centers, and the division offices will be managed.

The FHWA reorganization plan does not identify an office with agencywide management responsibilities related to technology transfer, and responsibility for several important management requirements remains unassigned. Questions that need to be resolved include how a core business unit will learn from the technology transfer successes, or perhaps even failures, of another core business unit; who will be responsible for maintaining technology transfer communication channels among the core business units; and how technology transfer specialists from outside the agency (i.e., from state highway agencies, universities, and Local Technical Assistance Program [LTAP] centers) will be included in FHWA's technology transfer process. More specifically, the management requirements that need to be addressed in the FHWA reorganization include the following:

- Authority and responsibility for setting agencywide technology transfer priorities;
- Coordination of technology transfer activities across the core business units;
- Maintenance of internal expertise in the process of technology transfer;
- Identification of what works in the long run, in terms of both new technologies and technology transfer methods, for research products and FHWA's customers; and
- Means for monitoring and measuring the performance of technology transfer and progress toward goals.

FHWA's technology transfer activities lack a strategic focus.

The RTCC found OTA's organization, process, and materials for technology transfer to be based on a good intuitive grasp of information exchange and technology transfer. Nevertheless, the committee believes FHWA's technology transfer activities lack a strategic focus and reflect inadequate recognition of how technology transfer promotes innovation in the highway sector.

Many factors interact to make innovation difficult in the highway sector. Public-sector consumers of technology are not interested in cre-

ating new products or making a profit. Competition for highway construction projects is usually based on cost but seldom on innovation. When public works decision makers seek performance improvements or cost savings through innovation, they are frequently confronted with certain higher initial costs and uncertain future benefits in an environment that does not reward risk taking. In addition, highways and bridges are generally large, complex, and long lasting, so innovation must be assessed in terms of initial costs, expected performance, and projected maintenance costs. Procurement is often legally bound to a low-bid approach in which the emphasis is on design specifications rather than performance specifications, an approach that discourages bidders from offering innovative alternatives.

While past studies report good practices and key characteristics of successful technology transfer, there appears to be no simple, universal recipe for successful innovation in the highway sector. Past successes in technology transfer confirm the potential for innovation, but the best approaches are often context or technology driven. Because the highway industry is highly diverse, the participants and processes in the various technical areas differ significantly. Achieving innovation in pavement or bridge design is quite a different task from achieving innovation in planning. In addition, the highway industry consists of many entities that are public and private, large and small, simple and complex, independent and interconnected, and always changing. Successful technology transfer in this environment involves hard work, team effort, creativity, and commitment on the part of all participants.

Despite the challenges it presents, innovation is critical to meeting increasingly complex and interrelated highway system needs, especially as travel demand grows much more rapidly than system capacity. Yet if improvement is to be achieved through technology, innovation must occur at a more rapid pace than in the past, and will require considerable effort and an improved strategic focus on the part of FHWA. Faced with a reduced technology transfer budget, FHWA must give considerable attention to developing a workable strategy for technology transfer. (A later section presents the committee's proposed strategy.)

Key characteristics of successful technology transfer should guide the execution of any technology transfer strategy adopted by FHWA.

On the basis of a literature review, the committee identified a number of key characteristics of successful technology transfer that should guide the execution of any technology transfer strategy adopted by FHWA. Although these characteristics may appear obvious, there is evidence that they are often overlooked.

Early involvement of potential users in the research planning phase helps ensure that research products respond to user needs. Researchers and research managers should ask potential users what they need and then develop products with user assistance and input.

Inclusion of *field tests, demonstrations, and pilot projects* as part of R&D activities helps potential users decide whether to implement new technology and helps developers refine the technology prior to widespread implementation.

Incentives such as implementation funds or other financial and technical assistance designed to support early implementation of new technology are favored by implementing agencies. Since early adopters of new technology are often closely watched by others, sufficient funds are needed to complete initial or pilot installations so that early implementation activities do not fail because of a lack of funds.

Successful innovation always requires *senior management support* and sometimes specific agency management action to organize that support. Previous technology transfer efforts have shown the value of having *a champion for a new technology* within the user agency; thus early attention should be given to establishing and supporting champions among the user agency decision makers.

Most new technologies require *technical training*, especially if in-house staff do not have the required expertise. Although user-friendly innovation is a worthy goal of R&D, the problems being addressed often require technologically complex solutions. In many cases, extensive staff training is needed for both implementation and operation if a new technology is to succeed. Such training may also address potential internal resistance to change.

Changes to standards and specifications may be needed to accelerate the implementation of certain technologies. Because so much of public-sector procurement is closely governed by standards and specifications, researchers, technology transfer staff, and potential technology users need to identify and work closely with the relevant standards-setting bodies so that if changes to standards and specifications are needed, they can be made quickly and efficiently.

Finally, technology transfer programs must include *careful monitoring of acceptance, adoption, refinement, and satisfaction among users of the technologies* being promoted. Such information is needed for managing technology transfer activities and for successfully assessing progress toward the goals of those activities.

PROPOSED FHWA STRATEGY FOR TECHNOLOGY TRANSFER

As suggested above, FHWA needs to articulate a strategy for its technology transfer activities. A strategy provides guidance for resource allocation, aids in making choices about specific activities and target groups, helps monitor progress toward goals, and provides guidance in determining when a specific technology transfer activity should be scaled back or concluded. The following proposed strategy has four components that can form the basis for future FHWA technology transfer activities. Together these components represent a conceptual framework identifying the key issues FHWA must address to foster more innovation in the highway industry. Within this framework, FHWA needs to give full consideration to the many participants and activities involved in technology transfer within the highway industry. The agency also needs to develop specific procedures and practices for carrying out the strategy.

Basing Technology Transfer on Knowledge About Research Products and the Technology Users

Much of FHWA's technology base originates in research conducted or sponsored by FHWA, state highway agencies, the National Cooperative Highway Research Program, universities, and the Strategic Highway

Research Program. Technologies from these sources can be identified through research reports and contact with researchers and technical specialists involved in their development, as well as TRB, professional associations and journals, and the private sector. In addition, through its international technology scans and continuing reviews of emerging developments in other fields, FHWA is in a position to identify a broad range of technologies that can help meet highway industry needs.

The state highway agencies that build, operate, and maintain much of the nation's highway system are the primary users and purchasers of the products of highway research. Other users include local highway and transportation agencies, contractors, standards-setting bodies, consultants, and manufacturers. Also important are decision makers at the state and local levels who determine whether to fund the implementation of new technologies. Identifying the primary users of a technology and those who can be most influential in its implementation is critical to FHWA's technology delivery mission.[2] This information is important because early involvement of potential users in R&D activity—even before a technology is ready to be implemented—has been shown to be a key determinant of successful implementation. Such involvement familiarizes users with the products being developed; helps researchers define the problem more clearly; and fosters a better understanding of the cost limitations, usefulness, and adaptability of new technologies. Early user involvement can also help FHWA identify potential initial implementing agencies that may become strong supporters or champions for specific technologies, as well as assist the agency in selecting appropriate technology transfer methods.

Setting Technology Transfer Priorities

Faced with a wide array of both potential users and research products, FHWA must make critical choices about where and how its limited technology transfer resources will be used. The setting of priorities must precede the selection of technology transfer methods and the initiation of implementation. Setting and revising priorities are part of a continuing process that requires specific guidelines and procedures. Priority setting should be based on such factors as FHWA's strategic goals,

expected technology benefits, the extent of user interest, the need for financial incentives, potential product commercialization, and opportunities for private-sector partnering.

Choosing Appropriate Technology Transfer Methods

Technology transfer is a complex process for which no standard methodology is available. Yet knowledge of the research product and its users is always an important first step in identifying appropriate technology transfer methods for various customers. The nature of the technology—as indicated by its range of potential applicability, degree of hardware dependence, and adaptability—affects technology transfer choices, as do user and user organization characteristics. FHWA's program goals, incentives, and organizational structure for performing technology transfer and providing technical assistance also affect appropriate choices. Understanding what has worked in the past in specific technology areas from the wide range of available technology transfer mechanisms is helpful as well. Selecting a technology transfer method involves knowing the audience, identifying appropriate information for that audience, and evaluating the technology transfer task in terms of cost and schedule. As a result, choices among available approaches must be made in close coordination with the priority-setting process mentioned above.

Measuring the Effectiveness of Technology Transfer Efforts

The purpose of measuring the effectiveness of technology transfer efforts is twofold: to determine whether those efforts are making progress toward the goal of widespread implementation, and to determine and document which methods work best for specific product–customer combinations. Such measurements are necessary to achieve continuous improvement in the overall technology transfer program and to help satisfy agency performance requirements. In addition, they provide a basis for documenting accomplishments within the R&D program.

Measuring effectiveness is not the final step in the technology transfer program; rather, innovation is a continuous process that involves

many feedback loops. For a mission agency such as FHWA, it is also a continuous learning process. While technology transfer can help achieve a high level of technology adoption, it can also provide information that leads to changing or concluding a specific technology transfer effort because the potential benefits cannot justify the resources being expended. Such information and the decisions it supports are important to successful technology transfer programs. Better-informed decision making enables efficient resource allocation and supports the overall goal of accelerating innovation.

RECOMMENDATIONS

FHWA should assign agencywide management responsibility for technology transfer to one of its headquarters offices. That office should then prepare a management plan for future FHWA technology transfer activities. The functions recommended here would differ significantly from those formerly carried out by OTA. OTA's mission was to implement new technology. This recommendation is for an office with the mission of providing a strategic focus at the corporate level for technology transfer activities throughout the core business units. The recommended plan should describe how the office would coordinate future FHWA technology transfer activities across the core business units; the Office of Research, Development, and Technology service unit; and the field organization. Specific items that should be addressed in the plan include how FHWA will set agencywide technology transfer priorities, monitor individual technology transfer activities, and measure performance so it can learn what does and does not work.

FHWA's technology transfer management plan should include a strategy for the agency's technology transfer activities. This strategy should incorporate the key characteristics of successful technology transfer and the four strategy components outlined earlier. The committee believes FHWA needs such a fundamental strategy if it is to carry out its stated mission of delivering technology to the highway industry with the limited resources available.

Finally, FHWA needs to develop strong partnerships with those who use and implement highway technologies, as well as the deci-

sion makers who are responsible for funding related to innovation. The committee believes involvement of the user community is critical to the success of both R&D and technology transfer activities, and recognizes that FHWA has initiated efforts to identify and engage its technology partners. The agency should continue these efforts and bring its partners into the research phase of its technology development activities as early as possible to help define and direct the research effort. FHWA's partners, particularly the states, are much closer to the operating environment in which technology must succeed and are essential to successful implementation.

NOTES

1. Modification should be based on data on actual implementation benefits and information on the effectiveness of specific methods of technology transfer.
2. FHWA's technology transfer activities must reflect recognition of the changing federal–state relationship and the impact of such change on the relationship between FHWA and state highway agencies.

REFERENCE

ABBREVIATION
TRB Transportation Research Board

TRB. 1994. *Special Report 244: Highway Research: Current Programs and Future Directions.* National Research Council, Washington, D.C., 112 pp.

1

Introduction

Tell me and I will forget. Show me and I will remember. Involve me and I will know how.
(CHINESE PROVERB)

Innovation within the highway industry is important because it can help improve performance and safety; reduce environmental impacts; and reduce costs for the construction, operation, and maintenance of the nation's highway system. The importance of innovation is magnified as highway travel demand increases with little expansion of highway capacity, and with continuing growth in the repair and rehabilitation needs of heavily used highways. Approximately $101 billion is spent each year on building, operating, and maintaining the nation's highways (FHWA 1998). Now that the Interstate Highway System has been completed, state and local highway agencies have shifted their focus toward preserving and renewing the existing system. The needs in this regard are great. For example, the Federal Highway Administration (FHWA) estimates that during the next 20 years, nearly $178 billion will be required to significantly improve the condition of bridges (FHWA 1997). Accelerating the use of innovations that achieve even modest savings in materials, equipment, or processes can yield signifi-

cant benefits to the highway industry, particularly as those innovations are adopted by more highway agencies across many projects.

BACKGROUND AND PURPOSE

State and local highway agencies face a growing backlog of highway repair, maintenance, and reconstruction needs on many key sections of the nation's highway system. These sections often serve high traffic levels and cannot be shut down for rehabilitation or reconstruction without causing major disruptions for road users and adjoining communities. Innovations in construction, materials, equipment, and construction traffic management could help reduce the need to close highways for extended periods of time, and thereby avoid considerable inconvenience and increased delays for road users, major community disruption, and significant economic loss.

Generally speaking, innovation is aimed at lower cost, higher quality, or improved performance. "Whatever else may be involved, innovation only occurs when ideas are used; i.e., it must include deployment ... *and use*" (Kash 1989, 24). In other words, successful innovation requires implementation. Research is needed to provide new products, methods, materials, and practices for the highway industry, and technology transfer is needed to ensure that research results are implemented by state and local highway agencies, contractors, materials suppliers, and other components of the highway industry.[1] The purpose of this report is to examine innovation and technology transfer activities within the highway industry and to provide suggestions for improving and measuring the performance of FHWA's technology transfer efforts.

Achieving innovation is a complex process involving many people and activities, with the ultimate aim of implementation and use of research products in an operating environment (see Chapter 2 for a discussion of the innovation process). The innovation can be a new product or process, different materials for product components, or even a reorganization of the way tasks are performed to achieve efficiency. Tornatzky et al. (1990) describe innovation as both the new tool and the process of getting the tool used.

As important as innovation is, its implementation is not automatic in either the private or the public sector. Moreover, successful implementation is achieved differently in the two sectors, and technology transfer must account for these differences. Private-sector or commercial innovation focuses on using research results to develop commercial products offered for sale; market forces and progress control such innovation. The market provides a profit incentive for "fashioning new products, improving the performance of old ones, or producing products at lower cost" (Kline and Rosenberg 1986, 275). This incentive is not as significant in the public sector. Implementing innovation in the public sector involves a complex set of incentives that focus on improving performance or reducing cost. However, these incentives are often outweighed by several impediments (as discussed in Chapter 3) that tend to limit the rate at which innovations are adopted. Technology transfer—recently defined as the movement of technological and technology-related organizational know-how among partners (individuals, institutions, and enterprises) (NAE 1997, 2)—can accelerate innovation. Nonetheless, technology transfer and technical assistance programs often encounter considerable resistance, even when directed at specific changes based on sound evidence from well-conducted research and development.

Innovation and technology transfer are a major part of FHWA's long and distinguished history and are of paramount importance to the agency's mission, which involves continually improving the nation's highway system and its intermodal connectors.[2] In addition, FHWA recently reorganized to focus more on long-term planning and highway operations than on the construction of new highways. The FHWA headquarters structure now consists of five core business units and eight service business units in a matrix organization. The core business units address infrastructure, operations, planning and environment, motor carrier and highway safety, and federal lands highway. The service business units focus on policy; administration; research, development and technology; professional development; corporate management; civil rights; public affairs; and legal counsel. FHWA also closed its nine regional offices and established four technical resource centers to support the state-level division offices in their primary role of program delivery.[3] Each resource center is assigned a group of states in its respec-

tive geographic area, but specific technical expertise is shared among resource centers and division offices as needed.

FHWA's stated purpose for reorganizing was to emphasize its technology delivery function at a time when state and local highway agencies need new technologies to address highway problems resulting from heavy use, congestion, and deterioration. With no new major construction programs and fewer restrictions on federal highway funds, FHWA seeks to accomplish technology delivery through leadership and guidance in cooperation with state and local highway agencies. See Chapter 5 for a discussion of the implications of the reorganization for FHWA's technology transfer program.

ORGANIZATION OF THE REPORT

Chapter 2 describes the innovation process and the role of technology transfer in supporting innovation in the public sector. Chapter 3 provides an overview of innovation and technology transfer in the highway industry. Chapter 4 describes technology transfer activities within the highway industry; it also presents information about successful technology transfer obtained from several recent studies. Chapter 5 describes the committee's suggested strategy for future FHWA technology transfer efforts. Chapter 6 provides a summary and the committee's recommendations. In addition, three appendices are provided: Appendix A lists the research and technology delivery functions of FHWA's five core business units and the Office of Research, Development, and Technology; Appendix B gives examples of user involvement aimed at promoting technology transfer; and Appendix C describes FHWA's activities within the various technology transfer areas.

NOTES

1. The committee defines the highway industry as including the federal, state, and local government agencies that construct, operate, and maintain U.S. highways and the private companies that supply materials, equipment, and services used by these public agencies.

2. The five mission goals of FHWA's 10-year strategic plan are safety, mobility, productivity, protection of the natural environment, and national security (Betsold 1998).
3. The resource centers support the state-level division offices by providing leadership on strategic initiatives and expert assistance on technical process and program issues, training, technology transfer, intermodal and interagency coordination, legal services, and civil rights. Each state, as well as Puerto Rico and the District of Columbia, has an FHWA division office.

REFERENCES

ABBREVIATIONS

FHWA	Federal Highway Administration
NAE	National Academy of Engineering

Betsold, R. 1998. The State of Research. *Public Roads.* Nov.–Dec.

FHWA. 1997. *1997 Status Report of the Nation's Surface Transportation System: Condition and Performance Report to Congress.* U.S. Department of Transportation, Oct.

FHWA. 1998. *Highway Statistics 1997.* U.S. Department of Transportation, Nov.

Kash, D. E. 1989. *Perpetual Innovation: The New World of Innovation.* Basic Books, Inc., New York.

Kline, S. J., and N. Rosenburg. 1986. An Overview of Innovation. Pp. 275–305 in *The Positive Sum Strategy* (R. Landau and N. Rosenburg, eds.). NAE, National Research Council, Washington, D.C.

NAE. 1997. *Technology Transfer Systems in the United States and Germany.* National Academy Press, Washington, D.C.

Tornatzky, L. G., J. D. Eveland, and M. Fleischer. 1990. Technological Innovation: Definitions and Perspectives. Pp. 9–26 in *The Processes of Technological Innovation* (L. G. Tornatzky and M. Fleischer, eds.). Lexington Books, Cambridge, Mass.

2

The Innovation Process

Understanding the innovation process is essential to establishing strategies for technology transfer. This chapter begins by briefly describing the innovation process in the highway industry on the basis of a traditional linear model. This model is then revised to illustrate the dynamic nature of the process by including several communication and other linkages involving individuals, groups, and organizations. Finally, the discussion focuses on technology transfer and the adoption of innovations, the relationship between the two, and their role in the innovation process.

The development of models based on stages or activities of a process is a familiar mechanism for bringing order to and better understanding the process. Traditionally, linear models have been used to model innovation (Kline and Rosenburg 1986). Figure 2-1 presents such a model, used to describe the sequence of events from research idea to implementation of the research product in the highway industry (Kulash 1997). This model, representing the point of view of the source or production of technology, comprises seven stages. Research and develop-

ment (R&D) usually ends within Stage 4; technology transfer typically focuses on the activities within Stages 5 through 7.[1]

While the traditional linear model is a helpful beginning and highlights some of the major steps involved, it misrepresents the innovation process by depicting it as smooth and well behaved (Kline and Rosenburg 1986). A linear model of innovation is inherently limited because the process is not quite so simple. A linear model cannot describe the differences, relationships, and interdependencies among stages; the large number of participants involved; or the full array of activities required to achieve implementation. Consequently, such a model is inadequate for establishing strategies and providing guidance for the management of a technology transfer program.

Figure 2-2 presents a revised model of the innovation process that incorporates additional details reflecting characteristics of the highway industry. For example, once an idea has evolved into a research product, the product is available for use by state and local highway agencies. The revised model includes stages associated with specification and procurement obstacles, the contractors (and others) who will be asked to adopt and adapt to the innovation, and the specific project applications that will yield the benefits of use of the product. The model portrays these stages in both the vertical and horizontal dimensions to represent an innovation process that moves forward (horizontally) in time, as well as upward (vertically) to overcome resistance or barriers. Included in Figure 2-2 are some of the feedback loops and input channels that

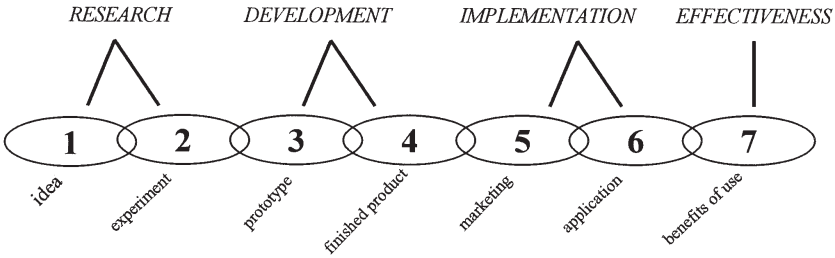
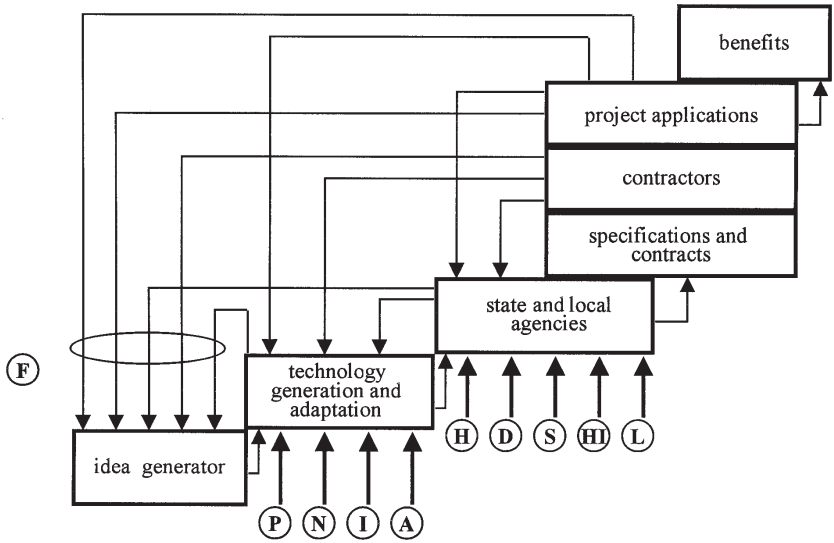


Figure 2-1 Linear model of highway industry innovation (Kulash 1997).



Legend:

I	**Innovations Deserving Exploratory Analysis**
N	**National Transportation Product Evaluation Program**
H	**Highway Innovation Technology Evaluation Center**
S	**Lead States Program**
D	**Early adaptor support**
F	**Focus group (e.g., owners, highway user groups, safety and environmental advocates)**
L	**Local Technology Assistance Program**
P	**Long-Term Pavement Performance Program**
HI	**National Highway Institute**
A	**Industry associations**

Figure 2-2 Revised linear model illustrating inputs and feedback by specific participants.

can affect highway industry innovation; others might be included, depending upon the particular technology involved.

No single model can adequately represent all the variations in stages, timing, participants, input channels, and feedback loops. Kline and Rosenburg (1986) propose a chain-linked model for innovation, showing flow paths of information and cooperation between and among

stages. Tornatzky et al. (1990) suggest that the stages of innovation should be defined not as steps on a stairway, but as rooms connected by a large number of doors.

Participants in the innovation process often provide new technologies, important feedback on implementation experience, new ideas for additional research, and assistance in fostering more widespread application. Some play multiple roles in research and implementation. Among the many highway industry participants and their contributions to innovation are the Federal Highway Administration (FHWA) and state highway agencies; committees and activities of the American Association of State Highway and Transportation Officials (AASHTO) aimed at standards setting and identification of research needs; research programs of state highway agencies that generate research products and carry out field tests; university R&D programs; Transportation Research Board (TRB) technical committee activities; association activities; and courses of instruction provided by the National Highway Institute on implementing specific technologies.

Analyses of private-sector innovation focused on product commercialization emphasize the need for continuous feedback among corporate researchers, marketing divisions, and potential customers, reflecting the need for responsiveness to marketplace demands. The link from research to innovation "is not solely or even preponderantly at the beginning of typical innovations, but rather extends all through the process" (Kline and Rosenburg 1986, 289). Consequently, research questions can and do arise throughout the development process.

Market forces that create incentives for innovation in the private sector operate differently in the public sector. Many innovations developed and adopted by private contractors are aimed at gaining a competitive advantage over other contractors bidding on public-sector contracts, rather than achieving an improved final product. The stimulus for implementing new technology in the public sector comes from regulations, financial incentives, expansion or new construction, or equipment or material failures. It can also come from technology transfer and technical assistance programs. Technology transfer is an enabling mechanism that supports and, particularly in the public sector, encourages and promotes innovation. A number of characteristics of the public sector, and the highway industry in particular, act as barriers

to innovation, and these barriers must be specifically addressed as part of the technology transfer effort (see Chapter 3).

TECHNOLOGY TRANSFER

As noted previously, technology transfer has been defined as the movement of technological and technology-related organizational know-how among partners. Technology transfer activities are aimed at (1) identifying innovative technologies available for use in the highway industry immediately or after some adaptation; (2) selecting and prioritizing technologies to be promoted to the highway industry; (3) determining, developing, and applying effective technology transfer methods to promote the technologies; and (4) continually modifying the technology transfer process in accordance with feedback on which technologies and which methods of technology transfer have been successful. Although the purpose of technology transfer in the private sector is to "enhance at least one partner's knowledge and expertise and strengthen each partner's competitive position" (NAE 1997, 2), public-sector technology transfer focuses on getting technology known and implemented. Howitt and Kobayashi (1986) suggest that technology transfer consists of complex relationships among organizations, with participants having significant interests at stake and perceiving varying incentives for becoming involved in technology transfer and implementation activities. Like the innovation process, technology transfer is usually iterative, involving many individual steps.

Technology transfer can begin when users describe specific needs to researchers or developers of technology. The process includes all the activities of the researchers, technology users, and technology transfer staff that lead to the adoption of new or different products or procedures (TRB 1998). Technology transfer can occur through informal interactions between individuals; formal consulting agreements; publications; workshops, personnel exchanges, and joint projects involving groups of experts from different organizations; and more readily measured activities such as patenting, copyright licensing, and contract research (NAE 1997).

The above definition of technology transfer encompasses both direct and indirect forms. Direct or active technology transfer is linked to

specific technologies or ideas and to more visible channels, such as cooperative research projects or partnering agreements. Indirect or passive technology transfer involves the exchange of knowledge through such activities as informal meetings, publications, workshops, and conferences. In the early stages of the technology life cycle, indirect technology transfer predominates, so it is often difficult to trace the origins of specific technologies or ideas. Nevertheless, a robust innovation process benefits from inputs and feedback from many sources.

Public agencies are particularly reliant on technology transfer programs for several reasons. The large volume of R&D under way and the dispersion of R&D agencies serve as deterrents to anyone seeking useful technical information, especially public agencies with limited financial resources and personnel. Few research products are self-executing, so users must rely on outside experts to understand how to adopt the new products effectively. Potential users need information on the limitations and capabilities of research products to avoid wasting time and resources in attempting to fit a technology to an incompatible use. Technologies that are particularly sophisticated, different from those currently used, or costly to adopt may require adaptation before being employed in specific applications or may necessitate considerable accommodation by the users (Lemer and Tornatzky 1991).

Without technology transfer programs, local public agencies would find it difficult to make decisions about new technologies (Bikson et al. 1996). Local agencies are often hindered by limited knowledge of innovative new technologies, a lack of funds for initiating programs involving such technologies, and limited technical expertise to assist in implementation (Jacobs and Weimer 1986). Professional and trade journals provide information, but technical details are often lacking. Moreover, "unlike their private counterparts, public managers cannot look to the profitability of competitors as an indication of successful innovation, and they are not punished in the marketplace for failing to adopt the most efficient technologies" (Jacobs and Weimer 1986, 139). As a consequence, technologies can be available for many years and widely adopted while they continue to be implemented for the first time by some local agencies. (See also Chapter 3.) Any improvement over existing technologies or processes, not necessarily a chronologically recent innovation, is new to the implementing agency (Schmitt et al. 1985).

INNOVATION ADOPTION

Studies of innovation adoption indicate that it involves several phases for both individuals and agencies (Rogers 1962) (see Table 2-1). Each of these phases benefits from technology transfer activity. During the initial awareness phase, potential users observe an innovation or new technology and decide whether to seek more information about it. In the next phase, attitude formation and persuasion, the potential user actively seeks more information and forms some initial impressions. The appropriateness of the innovation for the user's situation is then assessed, and an adoption decision is made. In the final phase, the user continues to seek information to confirm acceptance or rejection of the innovation. Figure 2-3 illustrates these phases relative to time and user involvement.

Another aspect of innovation adoption is important to technology transfer. Adoption of new technologies by implementing agencies varies over time. Some technologies are adopted quickly, while others never exhibit more than a slow rate of adoption. Although the concept of

Table 2-1 Phases in the Innovation Adoption Process

Phase	Description of User Involvement Phases
Awareness	A potential user first observes an innovation or new technology and gains some understanding of how it functions. Such awareness may be entirely passive; lacking complete information, the potential user may not yet be motivated to seek further information.
Attitude Formation and Persuasion	The potential user becomes interested in the innovation and actively seeks additional information in order to form some attitude toward it.
Trial and Decision	The innovation is assessed, and an adoption decision is made. A trial period may ensue. Performance is one of the decision factors.
Confirmation	The potential user continues to seek information to confirm the adoption decision made. A decision can be reversed if there is conflicting information.

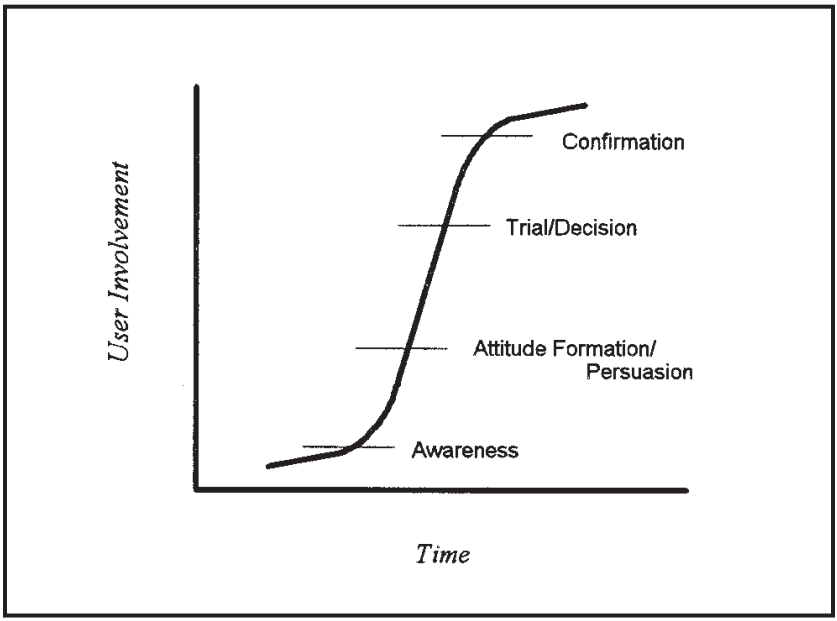


Figure 2-3 S-curve illustrating involvement of individuals at different stages of the innovation adoption process (Rogers 1962).

adoption rates is widely accepted, data are scarce for comparison purposes, especially for public-sector technologies. Moreover, at some point, demand for specific technologies tapers off; sometimes a new technology is overtaken by a more recent innovation (Feller 1981). As a result, there is a point at which technology transfer activity can be scaled back or dropped because further activity would be unproductive.

In most cases, moving technology from the research environment to an operating environment involves considerable technology transfer effort and resources. The effort goes beyond information dissemination and exchange to encompass technical assistance and user training (EPA 1991). Successful technology transfer programs depend on effectively segmenting user audiences, and tailoring strategies to those audiences and to different stages of the technology development

process. Successful programs also involve obtaining feedback from technology transfer clients to assess whether the technology exchange has been successful.

NOTES

1. Boundaries between the stages of innovation are not always well defined; there is considerable overlap of activity between all stages.

REFERENCES

ABBREVIATIONS

EPA	Environmental Protection Agency
NAE	National Academy of Engineering
TRB	Transportation Research Board

Bikson, T. K., S. A. Law, M. Markovich, and B. T. Harder. 1996. *Facilitating the Implementation of Research Findings: A Summary Report.* NCHRP Report 382, National Research Council, Washington, D.C., 24 pp.

EPA. 1991. *Innovative Technology Transfer Workbook: Planning, Process, Practice; Draft Version 1.* Prepared by Technical Resources, Inc., Washington, D.C., Aug.

Feller, I. 1981. The Diffusion and Utilization of Scientific and Technological Knowledge in State and Local Governments. Pp. 131–150 in *Technology Transfer by State and Local Governments* (S. Doctor, ed.). Cambridge, Mass., Oelgeschlager, Gunn and Hain.

Howitt, A., and R. M. Kobayashi. 1986. Organizational Incentives in Technical Assistance Relationships. Pp. 119–136 in *Perspectives on Management Capacity Building* (B. W. Honadle and A. M. Howitt, eds.). State University of New York Press.

Jacobs, B., and D. L. Weimer. 1986. Inducing Capacity Building: The Role of the External Change Agent. Pp. 139–162 in *Perspectives on Management Capacity Building* (B. W. Honadle and A. M. Howitt, eds.). State University of New York Press.

Kline, S. J., and N. Rosenburg. 1986. An Overview of Innovation. Pp. 275–305 in *The Positive Sum Strategy* (R. Landau and N. Rosenburg, eds.). NAE, National Research Council, Washington, D.C.

Kulash, D. 1997. Improving the Effectiveness of Highway Research: Reflections from the SHRP Experience. *TR News*, No. 188, Jan.–Feb., pp. 4–9.

Lemer, A., and L. G. Tornatzky. 1991. Processes of Technological Innovation. Appendix B in *The Role of Public Agencies in Fostering New Technology and Innovation in Building.* Committee on New Technology and Innovation in Building. Building Research Board, National Research Council, Washington, D.C.

NAE. 1997. *Technology Transfer Systems in the United States and Germany.* National Academy Press, Washington, D.C.

Rogers, E. M. 1962. *Diffusion of Innovations.* The Free Press of Glencoe, New York.

Schmitt, R. P., E. A. Beimborn, and M. J. Mulroy. 1985. *Technology Transfer Primer.* FHWA-TS-84-226, University of Wisconsin, July.

Tornatzky, L. G., J. D. Eveland, and M. Fleischer. 1990. Technological Innovation: Definitions and Perspectives. Pp. 9–26 in *The Processes of Technological Innovation* (L. G. Tornatzky and M. Fleischer, eds.). Lexington Books, Boston, Mass.

TRB. 1998. *Transportation Research Circular 488: Transportation Technology Transfer—A Primer on the State of the Practice.* National Research Council, Washington, D.C., May.

3

Innovation and Technology Transfer in the Highway Industry: Overview

This chapter provides an overview of innovation and technology transfer within the highway industry; specific technology transfer activities of the Federal Highway Administration (FHWA) and others are reviewed in Chapter 4. Characteristics of the highway industry and highway research programs that affect innovation and technology transfer are described first. Next is a discussion of FHWA's role in highway industry innovation and technology transfer. This is followed by a summary of the impediments to innovation in the industry.

HIGHWAY INDUSTRY CHARACTERISTICS

The nation's highway system—consisting of about 6.5 million km (4 million mi) of roads and streets, tunnels, bridges, and other structures—is essentially owned, operated, and maintained by state and local highway agencies.[1] These agencies contract with thousands of private

firms that furnish products, services, and equipment to build, maintain, and operate the system.

Although state and local governments have the primary responsibility for building and maintaining the nation's highway system, the federal government also plays an important role. The U.S. Department of Transportation, through FHWA, administers the federal-aid highway funding programs and develops regulations, policies, and guidelines to achieve national highway goals in these programs. FHWA administers financial assistance to the states; these funds totaled $21.6 billion in 1997. The primary source of this assistance is the Highway Trust Fund, a dedicated source of funding based on a federal vehicle fuel tax. Money from the Highway Trust Fund is distributed to the states on the basis of apportionment formulas determined by the U.S. Congress.[2]

Each of the 50 states, plus Washington, D.C., and the Commonwealth of Puerto Rico, has an independent highway agency. These agencies are responsible for those segments of the federal Interstate and primary highway systems that lie within their borders, as well as their own network of state highways; this amounts to about 20 percent of the nation's total highway mileage. Some of these agencies also have oversight responsibilities for all public and private highways within their states. In 1997 the states provided $55.3 billion for highway-related purposes through a range of means, including vehicle and driver licensing fees and fuel taxes.

At the local level, about 40,000 individual governmental units of varying size and population are responsible for 75 percent of the nation's highway mileage. The $29.6 billion spent in 1997 by local governments for highway purposes came primarily from local government general revenues; fewer than half the states allow local governments to levy user fees such as local fuel taxes.

The private-sector portion of the highway industry is made up of highway contractors and consultants; material and equipment manufacturers and suppliers; and the professional, trade, and industry associations at the national, state, and local levels that represent those involved in highway construction, operation, and maintenance. Thousands of individual businesses varying in size from multinational corporations to single-person operations provide products and services ranging from

tunnel and bridge construction to snow removal. Approximately half of all public spending for the highway system is on highway design, construction, rehabilitation, repair, and other work performed by private contractors, which in turn purchase materials and equipment from other businesses and hire subcontractors that do the same (TRB 1996).

RESEARCH AND DEVELOPMENT IN THE HIGHWAY INDUSTRY

Reflecting the way the industry is organized, highway R&D in the United States is decentralized and fragmented. Several federal agencies, the state highway agencies, many private companies and universities, and various public and private consortia conduct or sponsor highway R&D programs (TRB 1994). FHWA has the single largest R&D program (in terms of expenditures). Total research funding for the State Planning and Research Program (SP&R) exceeds FHWA's R&D funding, but none of the individual state programs is as large as FHWA's. The third major highway R&D program is the National Cooperative Highway Research Program (NCHRP), a pooled-fund program supported by state SP&R funds. As a result of the Transportation Equity Act for the 21st Century (TEA-21), surface transportation research has a budget of $85.7 million for 1999; the research portion of the SP&R program is about $123 million, with the largest state program totaling about $11.3 million. The NCHRP budget is about $22 million. In addition, private research is conducted or sponsored by major national associations of private industry and engineering professions concerned with highway transportation, and by companies that design and construct highways and supply highway-related products. Highway-related private-sector research funding could total as much as $86 million per year (TRB 1994).

The three major highway R&D programs have different characteristics (TRB 1994). The FHWA R&D program pursues practical research results that can be readily applied to problems of national significance, are common to many highway agencies, or are unlikely to be addressed by an individual state or private-sector organization. An example is the TRansportation ANalysis SIMulation System, or

TRANSIMS, a project sponsored jointly by the Office of the Secretary of Transportation, FHWA, the Federal Transit Administration, and the U.S. Environmental Protection Agency (see also Box 4-2 in Chapter 4). The purpose of TRANSIMS is to develop a completely new system of travel forecasting models for use by highway agencies and metropolitan planning organizations (MPOs) in estimating the transportation and environmental impacts of highway construction and rehabilitation alternatives. TRANSIMS will replace a set of models that is nearly 30 years old and cannot provide the travel and environmental impact estimates needed to meet current regulations. A research effort such as TRANSIMS requires a major, long-term funding commitment; the cooperation of many agencies; and broad oversight encompassing a strategic perspective.

State highway agency R&D is an important source of innovation in the highway industry. The research portion of the SP&R program is a major part of this activity and is supported cooperatively by individual states and the federal government (TRB 1994). In 1992 Congress took two steps that increased R&D funds available to the states: it increased the percentage of highway construction funds to be spent by the states on planning and research to 2 percent of the total apportionment, and it required that at least 25 percent of this funding be used for research, development, and technology transfer. As a result, about $69 million in SP&R funds was available for research in 1992, as opposed to about $25 million in the previous year. This amount had increased to $77 million by 1998. When TEA-21 increased the overall apportionment to the states beginning in fiscal year 1999, SP&R funding for research rose to a projected $123 million.

SP&R research involves a range of activities, including contract research, in-house research, technology transfer, technical assistance to regional and local transportation agencies, materials and equipment testing, and staff technical development and training. SP&R studies tend to be short in duration (1 to 2 years) and emphasize practical solutions that can be applied quickly to existing programs and problems. Often this research is aimed at correcting unique local problems related to a state's own conditions, including traffic levels and local construction materials; however, results of SP&R studies are often of interest to other states, especially those in the same geographic region. SP&R studies are

undertaken by state R&D staff or performed under contract by outside research organizations, university researchers, and consultants. Much of the testing, technical assistance, and technology transfer activity performed by state R&D personnel involves direct, one-on-one interaction with staff of other organizations who have specific questions or issues to be resolved. An example of a recently completed SP&R research project is presented in Box 3-1.

NCHRP, which is administered by TRB, is the largest state-supported pooled-fund research program.[3] The program emerged soon after construction started on the Interstate system, when many states began to experience similar problems related to highway design and construction. Since 1965 NCHRP has provided more than $175 million in funding for research on a wide range of topics (see Table 3-1 for a breakdown of this funding by category). NCHRP projects are oriented to problem solving and designed to produce results that have immediate application to highway agencies in all states; two-thirds of the member departments of the American Association of State Highway and Transportation Officials (AASHTO) must approve NCHRP research problems and agree to their financial support before they are brought into the program.

NCHRP project results are disseminated to states in a special TRB report series. Implementation is facilitated by the program's close ties to state highway agencies, which provide volunteers for the project review panels, and to AASHTO, which often develops highway design practices and specifications based on the research findings. (See Appendix B for more information on NCHRP support for implementation efforts.) A recent project resulted in a manual that highway agencies can use in planning, designing, implementing, operating, marketing, and enforcing high-occupancy vehicle systems (NCHRP 1998b).

FHWA ROLE IN INNOVATION AND TECHNOLOGY TRANSFER

FHWA has a long and distinguished history in highway industry innovation, beginning with its predecessor, the Office of Road Inquiry (ORI), which was established in 1893. As states and localities started building roads, ORI began gathering information about highway laws,

Box 3-1

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Example of Focused State Research

In response to a federal requirement for improved pavement design procedures and for state pavement management systems, one state department of transportation organized a 3-year research project using falling weight deflectometer (FWD) technology to measure the condition and performance of pavement designs over time. The project used the FWD to develop data on seasonal and temperature variations and changes in pavement conditions over time resulting from pavement distress.

In 1990–1991, on the basis of experience gained by the pavement management group, the department produced a written procedure for use of the FWD. With the dissemination of this procedure and the continued development of expertise, FWD use in the state has increased. Currently, all projects on Interstate highways use data from the FWD, except in a few areas (such as ramps) where traffic control prevents measurements.

FHWA's division office supported the research effort, and encouraged the pavement unit as it performed the work and overcame resistance to change within the state highway administration. The pavement unit continues to market the benefits of the FWD aggressively to division and district engineers. The department has instituted use of the FWD as standard practice, the equipment is used statewide, and the department has achieved its goal of developing a method for pavement design that more closely reflects local conditions in the state.

road-building materials, and the rail rates for those materials. This information was published in bulletins and distributed to the states, which used it in organizing their individual highway agencies.

During the Interstate highway era, which began in 1956, FHWA focused considerable research attention on construction and materials

Table 3-1 NCHRP Research Areas, Project Topics, and Research Expenditures (1965–1998)

Research Area	Topics	Number of Projects and Project Funding
Administration	Economics Law Finance	59 projects $6,380,015
Transportation Planning	Forecasting Impact analysis	75 projects $22,073,122
Design	Pavements Bridges Roadside development Vehicle barrier systems	186 projects $43,592, 694
Materials and Construction	General materials Bituminous materials Specification, procedures, and practices Concrete materials	138 projects $30,464,332
Soils and Geology	Testing and instrumentation properties Mechanics and foundations	25 projects $7,875,258
Maintenance	Snow and ice control equipment Maintenance of way and structures	37 projects $5,661,283
Traffic	Operations and control Illumination and control Traffic planning Safety	146 projects $34,695,080
Special Projects	Projects not readily identified with other problem areas	189 projects $24,372,679

issues related to the program. As major portions of the Interstate system were opened for use, interest in such topics as emerging concerns about the impacts of highways on urban areas and on the environment resulted in a broader range of FHWA research. With the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), FHWA

entered the post-Interstate era. ISTEA focused attention on the intermodal nature of the surface transportation system and the role of highways in that system.

As the breadth of its research increased, the scope of FHWA's technology transfer efforts widened as well, in recognition of the fact that implementation of its research products would depend on state and local highway agencies that build, operate, and maintain the nation's highways. Attempts were made to bring researchers and users together through such efforts and the federally coordinated program (later termed the nationally coordinated program) of R&D. FHWA worked closely with AASHTO and individual states to find ways of accelerating the use of FHWA R&D products.[4]

The close working relationship between FHWA and AASHTO has been instrumental in fostering innovation. As the national association representing state highway and transportation officials, AASHTO also has an important role—both formally and informally—in highway innovation, serving as a coordinator, organizer, and forum for encouraging, reviewing, and priority ranking research activities. AASHTO, through its Standing Committee on Research (SCOR), plays a key role in developing the annual NCHRP research plan and is involved in other state cooperative research efforts. (FHWA is invited to provide inputs to SCOR during the plan development.) Finally, SCOR assists other AASHTO committees in identifying research needs; advocates funding for highway research; and helps coordinate state involvement in national research activities, such as FHWA's implementation of research products resulting from the Strategic Highway Research Program (SHRP).[5]

IMPEDIMENTS TO HIGHWAY INDUSTRY INNOVATION

As noted in Chapter 2, a number of factors serve as impediments to innovation in the highway industry because they limit or prevent innovation and its potential benefits. First, while innovation involves risk, public-sector decision makers work in an environment that does not reward risk taking. In particular, many public facilities are large with high fixed costs and long economic lives. As a result, construction inno-

vation must be assessed not only within the context of the original installation (i.e., the way the facility is constructed and its initial cost), but also over a very long time period (i.e., whether it will continue to perform as expected and the cost to maintain it). Thus, public officials prefer familiar solutions that limit unexpected consequences. If they are unfamiliar with a new technology or uncertain about its benefits, they are reluctant to use it.

Second, public-sector procurement activity is driven by a low-bid process based on specifications and procedures established to satisfy the need for open competition and accountability.[6] However, these procedures can discourage contractors with new products or processes because specifications often determine how facilities are to be built, the types of materials to be used, designs to be followed, and construction processes to be applied. New technologies or materials with the potential for improved performance may not meet existing design specifications. Thus, attempts to introduce innovation and reduce life-cycle costs can be stifled. Furthermore, in a procurement environment dominated by selection based on lowest initial cost, the private sector is not motivated to invest in R&D if it cannot retain the ability to capture the financial benefits of the research products.

Another major impediment to innovation is fragmentation within the highway industry. Public ownership of the highway system is spread over more than 40,000 agencies with an assortment of political, regulatory, and administrative characteristics, as well as differences in size, budget, and staff capabilities. "Fragmentation results because no single government agency or organization is responsible for the state of a particular category of public works [such as highways]" (NCPWI 1988, 123). Fragmentation, disagreement among public works constituencies, and competition among public works categories for scarce resources have combined to constrain innovation.

Fourth, public-sector innovation is not subject to the profit motive that stimulates commercial innovation. When public works decision makers seek performance improvements or cost savings through innovation, they are often confronted with certain higher initial costs and uncertain future benefits. Although innovative technology can solve problems and reduce costs, public decision makers, who are often several layers removed from researchers and technology specialists, must

make judgments in an atmosphere of intense public scrutiny and accountability with regard to the technical merits and financial benefits of new technology. If public officials are unfamiliar with the potential of innovative technology or uncertain of its merits, they are reluctant to adopt it.

Innovation in the public sector is constrained still further by a set of factors associated with specific construction-related activities.[7] Since innovation successes in high-technology manufacturing are often cited as evidence of the potential for innovation, understanding how construction of public works facilities differs from those manufacturing activities can provide insight into ways of identifying, organizing, and focusing technology transfer activities for the public sector. Public facilities are usually built by a temporary alliance of contractors and subcontractors within an explicit professional, social, and political context. The contractor team disbands after the facility is completed, leaving the owner agency responsible for the operation and maintenance of the constructed facility. In addition, construction of public facilities, as opposed to high-technology manufacturing activity, involves considerable variations in local materials and conditions and a generally harsh operating environment, further discouraging divergence from standard design guides and prescribed methods and limiting the use of new ideas and methods (TRB 1994). The size, high cost, and permanence of these facilities make it difficult to conduct many full-scale tests and evaluations of innovations because of the time and expense involved. Finally, highways usually pass through multiple jurisdictions, adding to the need for uniformity and standardization in design and construction.

Construction innovation is also constrained by professional, social, and political factors that affect how innovation takes place. "Because constructed facilities directly influence the safety, health, and well-being of the population, all portions of a facility's life cycle (design, construction, operation, and decommissioning) are circumscribed by codes and regulations" (Slaughter 1998, 227), such as procurement procedures, design specifications, and safety and environmental guidelines.

Finally, the way public agencies are organized affects the speed of adoption of innovations. Local agencies are often hindered by limited knowledge of new technologies, lack of funds for initiating new programs involving innovative technologies, and limited staff technical

expertise (Jacobs and Weimer 1986). "Full information about what has been learned about a problem is frequently not assembled" and often underevaluated (TRB 1998, 6). Relevant public works R&D programs have been described as generally underfunded; scattered; and directed at diverse, specific program objectives (COTA 1991). As a result, public agencies are limited in their ability to identify, evaluate, and utilize innovations.

Table 3-2 summarizes many of the barriers to highway industry innovation. Overcoming these impediments requires considerable effort from both the private and public sectors. Some impediments to innovation, such as low-bid procurement or detailed design specifications, were put in place to ensure financial accountability or to avoid the use of inferior materials or products. Changes or modifications to allow the use of new technologies must be made in a manner consistent with the goals of these policies and procedures. In some cases the new product or technology necessitates a trade-off between conflicting goals or requires the public sector to assume a higher level of risk.

SUMMARY

Achieving innovation in the highway industry is a difficult task because the industry is highly fragmented and decentralized in all aspects, including its R&D activities. Moreover, although FHWA has the largest single highway R&D program, it does not implement the products it develops and promotes. Rather, those products are implemented by state and local highway agencies, construction companies, contractors, consultants, and others, making information about specific applications and benefits difficult to obtain. Consequently, FHWA must work closely with the technology users if research products are to be implemented.

Implementation of innovations in the highway industry faces a range of impediments that exist throughout the public sector. Many of these impediments stem from the need to ensure public accountability and safety for major public investments. While the public sector and the highway industry are working to overcome these barriers without compromising accountability or safety, much remains to be done in this regard.

Table 3-2 Principal Impediments to Innovation in Highway Transportation

Impediment Category	Type	Description
Technical	Testing and demonstration	New technologies need to be tested and demonstrated thoroughly before public agencies will accept them in competition with other, well-established technologies.
	Standards	Standards-setting groups that offer a safeguard against unexpected failure are often slow and deliberate and can delay implementation of innovative solutions.
	Testing to failure	Long-term testing is difficult and expensive and can preclude innovative solutions that are large and/or expensive.
Procurement	Disclosure rules	Public-sector disclosure rules can prevent the use (and advantages) of a proprietary design or process.
	Low-bid contracts	Such contract awards do not account for future operating and maintenance costs and can result in higher total costs.
	Life-cycle costs	Making awards based on life-cycle costs is difficult; adequate information on such costs may not be available
	Specifications	Public agencies rely on design or method specifications. This can discourage innovative techniques and products that could be considered if performance specifications were used.
Legal	Design–build limitations	Requiring that separate firms provide design and construction dampens the potential for innovation.
	Product liability and insurance costs	The potential for product liability tort claims, high insurance costs, and prospects for litigation discourage both the development and application of new techniques and products.

continued on next page

Table 3-2 *continued*

Impediment Category	Type	Description
Legal *(continued)*	Community participation	Technical choices are open to such intense public scrutiny that officials avoid controversy by relying on engineering design standards that simply repeat previous practice.
	Permit processes	Federal, state, and local permit processes are needed to protect public health and safety, but can preempt consideration of innovative solutions.
Public-Sector and Institutional	Resistance to change	The natural tendency to resist change and the conservative nature of public-sector organizations institutionalize this resistance.
	Lack of institutional incentives	Highway agency engineers have little incentive to examine new or innovative technologies to solve familiar problems.
	Limited agency capabilities	Highway agencies with limited technical capabilities may be unable to maintain complex new technology.
	Interest group resistance	Many organizations and interest groups committed to preserving the status quo act as a check on innovation.
	Effect of political patronage	Political patronage can dilute agency technical competence, further reducing the incentive for innovation.
	Employment practices and work rules	Employment practices and compensation can restrict the ability of public agencies to hire personnel needed to implement and maintain new technologies.
	Technology mismatch	There are possible mismatches between technologies employed today and those needed to meet future demand, as well as possible mismatches between existing and future job skills.
General	Limited resources	Resources for R&D in the public sector are limited; the size and complexity of the market limit interest in infrastructure problems.

NOTES

1. Within this system, examples exist of every possible combination of public and private development, finance, operation, and ownership of right-of-way (Pisarski 1987).
2. The 1998 highway reauthorization bill contains a provision that states must receive at least 90.5 percent of their contribution to the Highway Trust Fund.
3. Smaller groups of states also cooperate on other pooled-fund projects addressing problems of local or regional interest.
4. A recent report by the TRB Committee on Technology Transfer provides considerable detail about the practice of technology transfer and the roles of various federal, state, and local agencies and organizations (TRB 1998).
5. SHRP was a 5-year, $150 million applied research program established by the U.S. Congress in 1987, aimed at improving the performance, durability, safety, and efficiency of the nation's highway system.
6. Public agencies are addressing this issue. The Contract Administration Task Force of the AASHTO Subcommittee on Construction recently prepared a document describing various nontraditional contracting techniques that have been adopted successfully by some states (AASHTO 1997).
7. This discussion is based on material in Slaughter (1998).

REFERENCES

ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
COTA	Congressional Office of Technology Assessment
NCHRP	National Cooperative Highway Research Program
NCPWI	National Council on Public Works Improvement
TRB	Transportation Research Board

AASHTO. 1997. *Primer on Contracting 2000.* Washington, D.C., Sept.

COTA. 1991. *Delivering the Goods: Public Works Technologies, Management, and Financing.* Congress of the United States. Washington, D.C., April.

Jacobs, B., and D. L. Weimer. 1986. Inducing Capacity Building: The Role of the External Change Agent. Pp. 137-150 in *Perspectives on Management Capacity Building* (B. W. Honadle and A. M. Howitt, eds.). State University of New York Press.

NCHRP. 1998a. *Research Results Digest 225: Putting Research into Practice: A Synopsis of Successful Strategies and Case Histories.* Washington, D.C., June, 18 pp.

NCHRP. 1998b. *NCHRP Report 414: HOV Systems Manual.* Washington, D.C., 817 pp.

NCPWI. 1988. *Fragile Foundations.* Washington, D.C., Feb.

Pisarski, A. E. 1987. *The Nation's Public Works: Report on Highways Streets, Roads and Bridges.* National Council on Public Works Improvement. Washington, D.C., May.

Slaughter, E. S. 1998. Models of Construction Innovation. *Journal of Construction Engineering and Management.* American Society of Civil Engineers. Vol. 124, No. 3, May/June.

TRB. 1994. *Special Report 244: Highway Research: Current Programs and Future Directions.* National Research Council, Washington, D.C., 120 pp.

TRB. 1996. *Special Report 249: Building Momentum for Change: Creating a Strategic Forum for Innovation in Highway Infrastructure.* National Research Council, Washington, D.C., 57 pp.

TRB. 1998. *Transportation Research Circular 488: Transportation Technology Transfer—A Primer on the State of the Practice.* National Research Council, Washington, D.C., 95 pp.

4

Highway Industry Technology Transfer Activities

This chapter examines the technology transfer activities of the highway industry. The context for these activities is first described. The activities of the Federal Highway Administration (FHWA) and other major highway industry organizations are then reviewed. Next, the factors that support successful implementation of innovations are identified. The chapter ends by presenting the committee's findings as guidance for future FHWA technology transfer efforts.

CONTEXT

The context for technology transfer within the highway industry is defined by FHWA's major role in identifying and developing research products for use by others. Essentially, FHWA does not implement technologies; it transfers them to state and local highway agencies, materials and equipment manufacturers and suppliers, contractors and consultants, and other users of highway research results. Within this

context, successful technology transfer must include recognition of the organizational boundaries between FHWA's technology transfer staff and the technology users, the nature of the technology, and the technology transfer techniques involved. Since FHWA does not implement technologies, its technology transfer staff does not necessarily have a full understanding of the needs and abilities of user organizations, their potential for acceptance of innovations, or the capabilities and responsibilities of their technical staff. Furthermore, cultural, geographical, and procedural boundaries can exist between FHWA and the users of highway technology. Factors such as the historical relationship between FHWA and state and local highway agencies and between FHWA technology transfer staff and potential users also make a difference.

The nature of the technology—as indicated by the range of potential applicability, the degree of hardware dependence, and the adaptability of the technology—can affect its implementation by the highway industry. Adaptability is important because highway technologies must be compatible with local conditions, standards, and expectations. Characteristics of users and user organizations—such as size, available resources, organizational rigidity, familiarity with technology, and what part of the organization adopts a new technology—have an impact on successful implementation. Technology transfer activity is also affected by FHWA's organizational structure, program goals, and incentives, and the ability of its staff to perform technology transfer and provide technical assistance.

Another important factor affecting technology transfer is the technology transfer mechanisms used. Technology transfer activities include workshops, seminars, and conferences; technical assistance; peer exchanges; cooperative research and development (R&D) projects; information dissemination centers; newsletters and fact sheets; technical reports; news releases; journal and magazine articles; and electronic bulletin boards. A technology transfer program usually involves a mix of such mechanisms (see TRB 1998). Success depends on segmenting user audiences and tailoring strategies to different audiences at various stages of the technology development process (EPA 1991). Farhar et al. (1990) suggest that selecting a technology transfer method involves characterizing the audience, identifying the appropriate information for that

audience, and performing an initial comparison of methods based on such factors as those shown in Table 4-1. Addressing these factors early in the technology transfer effort can lead to more effective technology transfer and more appropriate implementation of technology.

FHWA TECHNOLOGY TRANSFER ACTIVITIES

Technology transfer at FHWA is aimed at informing potential users about the benefits of innovative technology and helping state and local highway agencies overcome the various barriers to implementing innovations (see Chapter 3). From October 1990 to October 1998, most of FHWA's technology transfer activities were consolidated in the Office of Technology Applications (OTA) under the Associate Administrator for Safety and Systems Applications. OTA identified and assessed research products that could address problems, improve performance, or reduce costs in the highway industry. A significant recent effort involved assisting in the implementation of technologies that resulted from research conducted for the Strategic Highway Research Program (SHRP) from 1987 to 1992.

Much of the discussion in this section is focused on how OTA carried out its technology transfer function from 1990 to 1998. The com-

Table 4-1 Basis for Selecting a Technology Transfer Method

Characterizing the Audience	Characterizing Information	Comparing Technology Transfer Methods
• Size	• Complexity	• Objectives
• Location	• Degree of abstractness	• Cost
• Homogeneity	• Knowledge/skill	• Schedule
• Knowledge/skill level	• Volume	
• Stability/turnover	• Required/optional	
• Affiliation/position	• Stand-alone or not	
• Access to resources	• Time sensitivity	
• Learning styles		

SOURCE: Farhar et al. (1990).

mittee recognizes that the recent FHWA organizational changes will affect future technology transfer activities (see Chapter 5 for a discussion of those changes and their potential impact on future FHWA technology transfer). Yet the committee believes these activities, at least in the short term, will continue to be strongly influenced by the strategies and techniques developed and used by OTA because of the expected continuity of the technology transfer staff.

FHWA's technology transfer mission is to ensure timely identification and assessment of innovative research results, technologies, and products, and the application of those products and processes determined to be of potential benefit to the highway community.[1] Much of FHWA's technology transfer program was consolidated in OTA and encompassed almost all areas of highway technology, including asphalt and concrete pavements, structures, hydraulics, geotechnology, environment, safety, motor carriers, and traffic operations and management. OTA's program targeted the following:

- Preparing user manuals and implementation packages for technologies developed in the FHWA R&D program;
- Sponsoring field tests in selected states to verify laboratory developments;
- Displaying new technologies in the field for workshop and open house demonstrations;
- Installing/applying technologies on local highway segments for further demonstration and evaluation; and
- Incorporating and evaluating innovative products in federal-aid highway construction projects.

Highway technology includes products from FHWA-sponsored research, as well as research by universities, research institutes, and transportation agencies in the United States and abroad. OTA estimated that approximately 25 to 30 percent of its recent efforts involved research results stemming from FHWA-supported R&D. The range of technologies promoted by OTA parallels the range of topics addressed by FHWA's eight Research and Technology Coordinating Groups (RTCGs) (see Box 4-1).[2] As noted earlier, the primary customers (or users) of FHWA's technology transfer services are the state

Box 4-1

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FHWA's Research and Technology Coordinating Groups and Their Principal Focus Areas (1998)

Safety: human factors; enhanced driver visibility; highway safety information management; interactive highway safety design model; roadside safety hardware; engineering improvements for enhanced safety and operations.

Pavement, including materials: asphalt and portland cement concrete pavements; pavement design and management; system preservation; waste materials; long-term pavement performance.

Structures: a "find it and fix" program aimed at development and deployment of nondestructive evaluation technologies in support of bridge management systems, and high-performance materials that are stronger and more durable than current materials; issues related to operational needs; laboratory support at Turner-Fairbank Highway Research Center for the structures technology program.

Policy: efficient and timely highway data collection, management, and dissemination; policy analysis of economic, energy, and financing issues; tools for analyzing system condition, performance, and efficiency issues.

Motor carriers: long-term focus on human factors improvements; reduction of risks associated with movement of hazardous materials; support for improved information analysis; regulatory review.

Planning, right-of-way, and environment: Travel Model Improvement Program and TRANSIMS development, statewide intermodal planning methods, and multistate economic development studies; air and water quality issues, wetlands, environmental process, and community impacts and public involvement; optimizing of real estate and right-of-way practice.

continued

Box 4-1 *continued*

Intelligent transportation systems (ITS): advanced traffic management systems; advanced traveler information systems; commercial vehicle operations; advanced traffic management systems; traffic analysis and operational design aids; institutional and legal issues.

Highway operations (innovative contracting, construction, maintenance, quality, etc.): long-term goals of improving the quality, service, life-cycle cost, and safety of pavements and bridges in the national highway system.

transportation agencies; local highway agencies, materials and equipment manufacturers and suppliers, and contractors and consultants are also major users of highway research results (Griffith 1990). Furthermore, FHWA's technology transfer services extend to highway transportation communities in countries throughout the world (Harder 1995).

The OTA program focused on four broad project categories: demonstration, application, test and evaluation, and special projects (Harder 1995). Technical activities were assigned to one of these project categories on the basis of the degree of application readiness of the technology, and which technology transfer or marketing approach FHWA chose to use for reaching the intended users. The four categories were defined as follows:

- *Demonstration projects*—nationwide efforts to promote a proven material, process, method, equipment item, or other feature targeted by FHWA for adoption by the highway community.
- *Application projects*—individual efforts to assess, refine, or disseminate an emerging technology. Technology transfer methods used include regional or national seminars or workshops, specification recommendations, notebooks or pamphlets, instructional materials, open houses, and focused clearinghouses.

- *Test and evaluation projects*—aimed at evaluating innovative or emerging technologies identified as having a great potential for nationwide use.
- *Special projects*—evaluation efforts by industry and FHWA, in conjunction with state transportation agencies, to evaluate a material, process, method, or other feature. Such projects usually involved several control experiments (or operational tests), leading to a closeout evaluation. Special projects could lead to a demonstration project, a test and evaluation project, or a combination of the two.

Harder (1995) describes the paths followed in 12 technology areas from research through technology transfer to implementation. Those 12 technology areas were selected on the basis of suggestions from FHWA staff, a panel of highway professionals, and a literature search to demonstrate the role played by FHWA in technology transfer and to estimate the value of that role. Each area incorporated a variety of products and processes with significant roots in the FHWA R&D program; each was also the subject of prominent FHWA technology transfer efforts during the period 1984 to 1993. The 12 areas are listed below; more detailed descriptions of these areas and the specific technology transfer activities associated with each are provided in Appendix C:

- Scour monitoring and instrumentation,
- Geotextile engineering applications,
- Pavement management systems,
- Bridge management systems,
- Protective coatings,
- Seismic design of highway bridges,
- Work zone traffic control,
- Bridge inspection techniques,
- Highway drainage design,
- Driven piles/pile foundations,
- Avoidance/handling of construction contract claims, and
- Computer models for traffic engineering and operations.

A number of technology transfer activities were associated with almost all of these areas. These activities included courses developed

for the National Highway Institute (NHI) (see below), demonstration projects, application projects, engineering circulars and manuals, technical advisory bulletins, training of FHWA technical specialists, computer programs, and coordination with the American Association of State Highway and Transportation Officials (AASHTO) to modify design specifications. Given the many individual and undocumented actions taken to transfer technology and the general lack of record keeping associated with technology transfer activities, Harder was unable to identify every technology transfer activity associated with each technology area. However, other methods were also identified, including brochures, fact sheets, newsletters, news releases, and journal and magazine articles; electronic bulletin boards; technical reports, papers, and presentations; workshops, seminars, conferences, and peer exchanges; and contacts with information dissemination centers.

To better understand FHWA technology transfer activities, the committee reviewed several examples of new technologies associated with FHWA research and technology transfer efforts. These examples illustrate the range of topics addressed by FHWA, the many steps and participants involved in technology transfer, some of the barriers to implementation, and the varying potential for commercialization. These examples are briefly summarized in Boxes 4-2 through 4-7.

OTHER TECHNOLOGY TRANSFER ACTIVITIES

Federally Supported Activities

FHWA supports the Local Technical Assistance Program (LTAP), NHI, the Dwight David Eisenhower Transportation Fellowship Program, and the Pan American Institute of Highways.

LTAP, the largest coordinated national transportation technology transfer activity, consists of centers in all states and the Commonwealth of Puerto Rico, as well as six Native American centers (TRB 1998). Federal funding for the centers is $100,000 per year from FHWA, plus an equal or greater local match. LTAP centers are operated principally through university continuing education offices, research centers, or

Box 4-2

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TRANSIMS (TRansportation ANalysis SIMulation System)

TRANSIMS is a completely new system of travel forecasting models currently under development by the Los Alamos National Laboratory (LANL) for the Travel Model Improvement Program (TMIP), a joint effort of the U.S. Department of Transportation (Office of the Secretary of Transportation, Federal Highway Administration, and Federal Transit Administration) and the U.S. Environmental Protection Agency. TRANSIMS is an interactive, simulation-based modeling system designed for estimating the transportation and environmental impacts of alternatives to highway capacity expansion in metropolitan areas (Ducca and Weiner 1996). It will replace a set of models that is nearly 30 years old.

Researchers, consultants, and planning professionals, including those at the metropolitan planning organizations (MPOs) that will use TRANSIMS extensively, have assisted in the development and refinement of the models through TRB and other committee activities. TMIP activities include publishing a newsletter that informs potential users about the status of developments and fostering an awareness of the potential and requirements of TRANSIMS. The fruits of these efforts are seen in recent MPO-initiated efforts to address how the 2000 U.S. Census can be used to meet TRANSIMS data requirements.

The size and complexity of such a computer simulation, coupled with new requirements for data collection and handling, changes in modeling capabilities, and complex analytical procedures associated with TRANSIMS, will pose problems for potential users at MPOs, especially those whose resources and technical capabilities are limited. There will be a long learning curve as people attempt to understand the model outputs and how to interpret them. Planning consultants will likely assist in this work, as well as prepare customized versions of TRANSIMS that will be offered to MPOs and other interested users.

Box 4-3

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Access Management Manual

Access management is a process aimed at providing access to land development in a systematic manner, while simultaneously utilizing the capacity of the surrounding road network and improving safety, maintaining traffic flow, and supporting safe operating speeds. The process includes determining access standards for various types of roadways, keying designs to these standards, incorporating the standards into legislation, and developing monitoring and enforcement procedures. Supported by empirical analyses and research studies, access management helps traffic engineers improve traffic flow and reduce accidents by separating decision points on multilane roadways. The access management manual currently under development addresses an important unmet need. It is the culmination of considerable research, analysis, development, and implementation involving FHWA researchers and engineers, National Cooperative Highway Research Program (NCHRP) researchers and panel members, several TRB committees, and state and local traffic engineers. OTA supported many development and implementation activities and sponsored three national conferences on access management.

Access management is a complex process involving four key elements that affect landowners, developers, business owners, and road users: legislation, technical guidelines, enforcement, and coordination among agencies. The manual will provide state and local traffic engineers with a systematic basis for addressing the various elements and parties involved.

Box 4-4

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Metallized Steel Bridge Coatings

Metallized steel bridge coatings consist of melted zinc or aluminum alloys sprayed in an airstream onto steel surfaces for corrosion control. When the sprayed metal strikes the steel, it resolidifies quickly to become a solid coating. Metallized coatings provide corrosion protection by means of sacrificial and barrier protection; they can be applied in the shop or in the field using a variety of techniques and equipment.

FHWA has supported research on bridge coatings for several years in response to regulations affecting the removal and disposal of existing bridge steel coatings containing toxic materials, volatile organic compound (VOC) limits on the applied coatings, and worker health issues impacting the alternatives and costs associated with corrosion protection of bridge steel. Using technology developed for the U.S. Navy, FHWA found that metallized coating systems provide long-term, maintenance-free performance, especially in severe coastal and salt-rich environments. Recent NCHRP synthesis reports address lead-based paint removal for steel highway bridges, and maintenance and corrosion protection methods for exposed bridge steel.

Metallized bridge coatings represent one of several alternative approaches to the corrosion problem, and the experience to date in just a few states has thus far yielded limited cost information. OTA organized an internal coatings team to coordinate with the states in determining their specific needs and to provide them with information on metallized coatings and other options. Development in this area will continue as the need grows for cost-effective alternatives that meet current regulations and address health concerns.

Box 4-5

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Mobile Unit for Measuring Retroreflectivity of Traffic Signs

In 1993 Congress directed FHWA to develop minimum retroreflectivity values for pavement markings and traffic signs. When the guidelines are approved, they will be applicable to all roads, streets, and highways in the United States. The directive recognizes that retroreflective paints and coatings degrade over time as a result of weather (signs and pavement markings) and wear (pavement markings). The establishment of minimum acceptable values means that highway agencies will need retroreflectivity measurements to certify that the values are being met. In addition, such measurements can help highway agencies ensure that the materials they use or have contracted for have the desired (and purchased) retroreflective performance characteristics, as well as measure the performance of retroreflective materials over time and manage installations and replacements by both contractors and agency personnel.

Tests by FHWA and state highway agencies have indicated that measuring a large number of highway signs requires a mobile unit to ensure the safety of the measuring crews and road users and to reduce the cost of data gathering. FHWA was involved in early work on technologies for measuring the retroreflectivity of both traffic signs and pavement markings. The private sector moved forward with development of a mobile unit for pavement markings, while FHWA remains instrumental in R&D of a mobile unit for signs.

NCHRP research sponsored by the state highway agencies yielded a breadboard system that was capable of measuring the average retroreflectivity of sign legends and background irrespective of color and size, and could be operated during daylight. A second NCHRP project demonstrated a prototype mobile reflectometer system based on commercially available components. FHWA is currently working with the Naval Research Laboratory to develop a mobile reflectometer that can be assembled from off-the-shelf components by state highway agencies or private firms. This approach was chosen to encourage commercialization of a proven system once the regulations have been issued.

Box 4-6

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Soil Stiffness Gauge

The soil stiffness gauge (SSG) is a lightweight, portable device that measures the in-place stiffness of compacted soil at a rate of about one test per minute. The SSG rests on the soil surface and produces a vibrating force measured by sensors recording the force and the displacement-time history of the ring-shaped foot of the device. The SSG is based on military technology that uses acoustic and seismic detectors to locate buried land mines. The device was developed through a partnership among FHWA and several manufacturers in conjunction with the U.S. Department of Defense with funds from the Technology Reinvestment Project of the Advanced Research Projects Administration.

Soil density was adopted decades ago for specifying, estimating, and measuring soil compaction because it is easily determined from weight and volume measurements. However, the process of measuring soil density is slow and labor-intensive and can be dangerous at construction sites. As a result, construction sites can be undersampled or poorly sampled, and this can lead in turn to insufficient information about and inadequate soil compaction. With current measurement techniques for soil density, it is not unusual to detect inadequate compaction after contractor crews have left the site; the result can be costly remobilization and corrective measures by contractors. On the other hand, compensating for potential inadequate compaction by overcompacting is time-consuming and costly.

Contractors and highway agencies currently rely heavily on the nuclear density gauge for measuring soil density. There are regulatory and licensing requirements for the use, transport, and disposal of this device, which also represents a safety risk for highway agency inspectors and contractor crews. Despite the SSG's advantages, it must overcome several hurdles before being widely accepted because it measures soil stiffness, a property not yet well understood by agencies and contractors. On the other hand, there is a growing trend toward mechanistic design of pavements and soil foundations, and mechanistic design requires more information about the stiffness of compacted soils.

continued

Box 4-6 *continued*

Although the SSG provides accurate measurement of soil stiffness and is cheaper, faster, and easier to use than nuclear devices, its initial value may not be in replacing soil density gauges. The device offers contractors a means of managing compaction activity more accurately and inexpensively. It also gives contractors a simple tool for ensuring that compacted soils meet specifications without the need for overcompacting, thereby reducing risks and costs. Moreover, contractors will have greater assurance that remobilization of equipment and crews to meet soil compaction specifications will not be necessary. In addition, the SSG could be a valuable tool in support of research into mechanistic design. It could also change the way soil compaction is managed and monitored. The addition of a Global Positioning System (GPS) unit to the SSG could provide highway agencies and other owners a means of linking SSG-generated soil stiffness data and location information to terminals at both contractor and highway agency sites. Such information would enable the contractor and the agency to jointly monitor and certify job activity; it could also serve as the basis for job warranty conditions.

Box 4-7

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Acoustic Strain Gauge

The acoustic strain gauge is based on electromagnetic acoustic transducers (EMATs) that use electromagnetic fields to generate and detect high-frequency stress waves in steel. The system measures the strain in steel members by detecting travel time changes in stress waves. The advantages of this gauge are that it attaches magnetically to a steel bridge with very little surface preparation, and that dynamic stress measurements can be taken quickly. The device provides an actual field test rather than measurements that must be entered into a theoretical analysis.

FHWA, West Virginia University, the National Institute for Science and Technology (NIST), and SonicForce LLC were involved in developing the gauge. Independent and concurrent efforts at the Constructed Facilities Center at West Virginia University, in conjunction with FHWA, and at SonicForce were aimed at developing a strain gauge based on EMAT technology. Separate inquiries made to the NIST laboratory in Boulder, Colorado, regarding EMAT technology eventually brought the two groups together. When it became apparent that the private sector would be developing a gauge, FHWA was able to provide the manufacturer with information about the potential highway industry market while discontinuing its associated R&D.

The highway industry is interested in the acoustic strain gauge because it is quick, accurate, and cheap and provides highway agencies with useful asset information. However, strain gauge development is fairly competitive and continues to evolve. New strain gauges keep getting cheaper and easier to use, but each requires development and testing before being widely implemented.

special units designated specifically to provide technical assistance to local officials. In some states, the LTAP center is operated by the state department of transportation.

The aims of the LTAP technology transfer centers are to transfer technology to local transportation agencies; improve communications among FHWA, state transportation agencies, local agencies, universities, and the private sector; encourage implementation of effective procedures and technology at the local level; and synthesize specific implementation experiences to serve as models for use elsewhere. The centers engage in a range of activities focused primarily on information exchange and dissemination, technical assistance, and training. They serve the more than 36,000 local highway agencies in the United States that range in size from single-person township departments to large city and county departments. The centers represent a large network for exchanging information and seeking advice. Associated with LTAP is the national LTAP Clearinghouse, operated by the American Public Works Association.

NHI provides comprehensive education and training programs tailored to meet the needs of surface transportation professionals at all levels of government—federal, state, and local. The NHI domestic program includes advanced courses in such topics as structures, hydraulics, ITS, pavements, safety, planning, environment, materials, geotechnology, traffic operations, construction, and maintenance. Internationally, NHI offers specialized courses addressing subjects such as technology transfer techniques, advanced pavement technology, and international bridge inspection.

In addition to providing specific courses, NHI makes training manuals and materials available to university professors for use in updating their courses. The Institute also conducts conferences, congresses, distinguished lecture series, seminars, symposia, and workshops; exhibits its services at World Trade Fairs; provides technical assistance to its international customers; administers an international personnel exchange program for FHWA offices; manages the programs of FHWA university transportation centers; and grants fellowships to students and faculty members who are pursuing or plan to pursue careers in transportation.

The Dwight David Eisenhower Transportation Fellowship Program was authorized by the Intermodal Surface Transportation Efficiency Act

of 1991 (ISTEA). The program provides fellowships to transportation professionals and targets faculty and college students at various educational levels. Students from senior-year undergraduates through postdoctoral fellows are encouraged to pursue careers in fields related to transportation. From 1993 to 1996 more than 440 fellowships were awarded through the program at a total cost of $10.8 million.

The Pan American Institute of Highways was established in 1987 to promote the exchange of technology among the members of the highway community of the Americas. The Institute has a central headquarters located within FHWA in Washington, D.C., and 82 national technology transfer centers in Central and South America. The centers coordinate technology transfer activities, distribute information, and organize seminars and courses.

University Activities

Universities are often closely identified with technology transfer activities, especially as educational, research, and public-service institutions. Many universities have well-established reputations in education and research focused on the needs of the transportation industry. In 1987 Congress established the University Transportation Centers Program (UTCP) by creating transportation centers in each of the 10 federal regions. When ISTEA reauthorized UTCP for an additional 6 years, 4 new centers were added. The 14 centers became focal points for addressing transportation issues and for attracting talent, resources, and facilities to promote individual initiatives and scientific innovation in a variety of transportation modes and disciplines. These centers have become important sources for research products and professional expertise, both of which are essential to successful innovation in the highway industry.

In 1998 in the Transportation Equity Act for the 21st Century (TEA-21), Congress again reauthorized UTCP and also added 19 new centers. The act authorized $158.8 million in transportation research funds for the program, plus an additional $36 million in transit funds, for fiscal years 1998 to 2003. TEA-21 established education as one of the primary objectives of a transportation research center, institutionalized the use of strategic planning in university grant management, and reinforced the program's focus on multimodal transportation. The act

created four classes of grants with different funding levels, competitive status, and life spans. See Box 4-8 for descriptions of the four grant classes.

State Highway Agency Activities

Each state highway agency is organized differently for research, development, and technology transfer. A survey of the states in 1989 indicated that 9 of 36 responding state highway agencies had designated technology transfer offices (NCHRP 1989).[3] Since that time, LTAP centers have been established in each state, and the states look to them for assistance in disseminating research results; this is the case particularly in those states in which the LTAP center is operated by the department of transportation (DOT).

Through AASHTO, the states have created four regional Research Advisory Committees (RACs), comprising the state highway agency research directors. The RACs support the mission of AASHTO's Standing Committee on Research (SCOR), whose members represent executive levels of the state highway agencies. That mission is to formulate and advise on transportation research, development, and technology transfer programs of national interest. The four RACs serve as technology exchange mechanisms among the state DOTs.

Other Related Activities

Two other recent developments support efforts aimed at innovation and timely implementation of new products in the highway industry. The Highway Innovative Technology Evaluation Center (HITEC) was created through the combined efforts of FHWA, AASHTO, TRB, the Civil Engineering Research Foundation, and other organizations. Using volunteer expert panels, HITEC provides central, independent screening and evaluation of innovative products for which no standard evaluation methods exist and assists innovators in gaining product acceptance.

The National Transportation Product Evaluation Program (NTPEP) was established within AASHTO to provide a single location for evaluation of standard products for which test methods or protocols have

Box 4-8

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University Transportation Centers Program as Authorized by TEA-21

Group A — $1 million per year for fiscal years 1998 through 2003 to each of 10 regional centers chosen competitively (the bill was passed too late for a competition to be held in 1998)

Group B — $300,000 per year for fiscal years 1998 and 1999, then $500,000 for fiscal years 2000 and 2001 to each of the following institutions/pairs:

- University of Denver and Mississippi State University
- University of Central Florida
- University of Southern California and California State at Long Beach
- Rutgers University
- University of Missouri at Rolla
- South Carolina State University
- Assumption College (Massachusetts)
- Purdue University

Group C — $750,000 per year for fiscal years 1998 through 2001 to each of the following:

- University of Arkansas
- New Jersey Institute of Technology
- University of Idaho
- University of Alabama
- Morgan State University
- North Carolina State University
- San Jose State University
- University of South Florida
- North Carolina A&T State University

continued

Box 4-6 *continued*

Group D $2 million per year for fiscal years 1998 through 2003 to each of the following:

- University of Minnesota
- Marshall University (West Virginia)
- George Mason University (with University of Virginia and Virginia Polytechnic Institute and State University)
- Western Transportation Institute (at Montana State University)
- University of Rhode Island
- Northwestern University

In fiscal years 2002 and 2003, the 17 grantees in Groups B and C will compete among themselves for 10 grants of $1 million per year.

already been developed.[4] NTPEP activities in each AASHTO region are coordinated by participating states. Existing facilities, equipment, and personnel in state highway agencies are used for the evaluations.

KEYS TO SUCCESSFUL IMPLEMENTATION

The committee reviewed several studies aimed at identifying those factors that support successful implementation of innovations. One of these studies addressed innovation in building technologies, and three addressed innovation in the highway industry.

According to an assessment of the building technologies research program at the U.S. Department of Energy's Office of Building Technologies, the earlier manufacturers are aware of and become actively engaged in the research, development, and demonstration process, the more quickly building construction-related technologies can be produced and commercialized (Farhar et al. 1990). Findings about the

program's technology transfer efforts were summarized in the form of the following basic principles:

- Early identification and segmentation of target audiences;
- Tailoring of programs to meet the needs and capabilities of the target audiences;
- Sufficient funding to permit continuity of effort; and
- Monitoring of utilization, coverage, and user satisfaction.

Farhar et al. (1990) also conclude that technology transfer programs should involve a clear statement of goals so the effectiveness of the program can be monitored and assessed. Because successful implementation of innovations is dependent on technology transfer efforts, assessments of the technology transfer process are as important as effective R&D in producing innovative products.

A second study reviewed was performed as part of SHRP. Under SHRP, a number of key products were delivered, including specifications, manuals, test methods, equipment, materials, and processes. As SHRP products became available for implementation, program staff identified common gaps or barriers that needed to be addressed before the products could be implemented by state highway agencies (SHRP 1990). These gaps included the following:

- *Staff training needs*—More than half of SHRP products require special training for state professional or technical staff.
- *Internal investment*—Most SHRP products require state investment in new laboratory equipment, field equipment, testing devices, or additional facilities.
- *Demonstrations, field tests, and validation*—Despite the testing performed on SHRP products, some states require additional testing and validation conducted at local sites, using in-state personnel and/or indigenous materials prior to implementation.
- *Procurement*—SHRP specification products are intended to yield higher-quality or longer-lived constructed facilities; they could result in higher initial costs for construction or some component material. Organizational policies or legal constraints can limit such options.

- *Prerequisite state management actions*—States must have information and management systems in place before several SHRP products can be implemented.
- *Need for accelerated adoption of standards*—Many of the key SHRP products are standards, specifications, or test methods designed to support specifications whose adoption rests with each individual state. The process of effecting change will be slow unless AASHTO, the American Society for Testing and Materials (ASTM), and other standards-setting groups accept the SHRP standards and use their influence to accelerate adoption within the states.
- *Other barriers*—Product-specific barriers call for tailor-made solutions. Their significance could be far greater than that of the more general barriers mentioned above. For example, a new asphalt binder specification requires the cooperation of the asphalt supply industry, as well as state-mandated changes.

SHRP staff, together with FHWA and AASHTO, worked to address these gaps and thereby overcome potential barriers to implementation. One of the more successful efforts was the creation of AASHTO's Lead States Program, which provides a means for state highway agencies to share with other agencies their early and extensive experience with the technologies developed or evaluated under SHRP (see Box 4-9).

A recent NCHRP project involved identifying and evaluating factors that influence the implementation of highway research findings and led to recommended strategies to facilitate the timely application of research results (Bikson et al. 1996). A broad definition of implementation was adopted that encompasses searching, testing, decision making, planning, procurement, contracting, training, modification, adaptation, and evaluation. Successful implementation was defined in terms of timeliness in putting research results to use, effectiveness in achieving desired results, and the proportion of potential users that have become actual users of the innovation. A workshop attended by representatives from state and local highway agencies and the private sector, together with a national survey of officials in state, county, and city transportation agencies, yielded information about what factors influence the successful application of research results in the highway industry.

Box 4-9

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Lead States Initiative

After completion of the 5-year, $150 million SHRP, AASHTO officials established the Task Force on SHRP Implementation to accelerate adoption of the program's research products nationwide. One of the major initiatives of the task force is the Lead States Program, launched in 1996 to ensure that practical, real-world experience with SHRP products will be shared among all state highway agencies. The program provides a mechanism for state highway agencies that have gained early and extensive experience with the technologies developed or evaluated under SHRP to share their experiences with other agencies. The goal is to encourage the implementation of these innovative technologies, to shorten the learning period for others, and to avoid unnecessary and costly duplication of effort.

Lead States have been designated in seven technology areas: the Superpave® system, high-performance concrete, anti-icing/road weather information systems, innovative pavement maintenance materials, pavement preservation, concrete assessment and rehabilitation, and alkali-silica reactivity. A Lead States team has been designated for each of these technology areas. Each team is composed of state highway agencies, along with associated contractors and suppliers, that have gained significant experience and expertise in the respective area. The teams are prepared to share information about field trials, research projects, events, training opportunities, publications, and other resources, as well as names and contact information for team members. In addition, the teams conduct on-line question-and-answer discussions about the technologies.

State and local highway agencies stated that the availability of funds aimed specifically at implementation efforts is far more important than the availability of research funds in explaining positive outcomes. The survey revealed that jurisdictional level makes a difference: state-level participants reported more implementation of innovations than did their city and county counterparts. Moreover, it was found that many local agencies do not consider themselves to be in the implementation business at all.

Highway agency representatives also offered their opinion on the most important implementation boosters. Rated highest were having results from pilot projects in user settings and having innovations that match user needs (see Table 4-2). Other important boosters include a strong commitment from highway agency senior management; adequate funding; collaboration among users, researchers, and vendors; user participation in the vital stages of R&D; and a champion for the project at the highway agency.

The survey also identified specific user needs in implementing new technology. For example, despite evidence that bringing researchers

Table 4-2 Twelve Most Important Implementation Boosters

Practice	Mean Importance Rating*
Pilot projects conducted in real user settings	4.6
Innovation matches users' needs	4.4
Strong commitment from senior management	4.3
Adequate funding	4.3
Collaboration among users, researchers, vendors	4.3
User participation in vital stages of the R&D	4.3
Champion for the project on site	4.3
High level of relevant technical skills	4.2
Implementation package and continued support	4.2
Demonstrable advantages for the innovation	4.2
Clear goals for the implementation effort	4.1
Targeted funding for the implementation	4.1

*Mean importance rating is based on survey responses from highway agencies using a scale of 1 (low importance) to 5 (high importance).
SOURCE: Bikson et al. (1996).

and users into closer and more frequent contact is an important tool for promoting implementation and users' belief that they should be involved in all stages of R&D, budget and time constraints, coupled with limited agency expertise, make it increasingly difficult to apply these approaches. Users believe they have ample access to information about innovations; however, they lack a useful mechanism for sifting through increasing quantities of disseminated information for relevance and quality. Finally, the researchers concluded that highway agencies do not capitalize adequately on the organizational learning that takes place during implementation because they tend to treat implementation efforts as one-time events. As a result, the experience they gain does not benefit future efforts.

Similar results were found in the study discussed earlier in which the technology transfer process was documented for each of 12 technology areas from research through implementation (Harder 1995). The study team identified the factors that strongly affect the success of FHWA technology transfer efforts. Chief among these factors were the following:

- Responsiveness to user needs;
- High level of user participation in testing, experimental installations, demonstrations, and pilot testing;
- Funding to support implementation;
- Presence of technical expertise in house;
- Presence of product/project champions and opportunities for peer exchange; and
- High-quality information dissemination.

In addition to the above studies, earlier work by the RTCC revealed that successful implementation could be characterized in terms of the following (Diewald 1992):

- Implementing innovations in the public sector usually involves a considerable amount of hard work, which often must be undertaken by individuals with day-to-day operational responsibilities that already consume all their available time.[5]

- A successful innovation usually has a champion who will not quit on the concept; sometimes there is more than one such individual. Innovation seldom occurs without a champion.
- Successful innovations are usually based on well-defined user needs with specific payoffs.
- Institutional barriers are probably the most difficult and time-consuming impediments to change, having been put in place for specific reasons that may still apply.[6]
- Successful innovation requires education and training for staff who are responsible for implementation. People are usually uncomfortable with change and will resist it if they do not understand its value.
- Many innovations are not simple one-to-one replacements for existing technologies, procedures, or equipment; they are more likely to affect a system in many different ways, making it difficult to evaluate their performance.
- Bringing potential users into the research process early on helps accelerate the development and implementation of innovations.
- Much can be done to encourage innovation, but it cannot be forced on an organization.
- Demonstration projects provide initial practical experience that can establish the basis for more widespread adoption.
- Many innovations require technical expertise and capabilities that do not exist at the operating level. Successful implementation will generally proceed more rapidly for user-friendly technologies.

The above studies provided the committee with considerable evidence of specific factors that foster the implementation of innovations. These factors are summarized in the following section as guidance for future FHWA technology transfer activities.

FINDINGS: GUIDANCE FOR TECHNOLOGY TRANSFER

Public agencies rely heavily on technology transfer programs for information, guidance, technical assistance, and even training. In particular, state and local highway agencies depend on FHWA for technical information and assistance in identifying and implementing innovative tech-

nologies. In addition, FHWA relies on these agencies for guidance regarding agency research needs. Although each of the studies reviewed by the committee examined different information and used different methods, they all generated conclusions—many very similar—about what is needed to accelerate innovation and technology implementation. The committee reviewed these conclusions and developed the following summary of keys to past success as guidance for future FHWA technology transfer activities. While some of this guidance may appear obvious, there is evidence that achieving a successful result requires attention to as many of these factors as possible (NCHRP 1998).

Early involvement of users: Research aimed at new highway technologies should be based on the needs of potential users/customers. Early involvement of potential users in the research planning phase thus assists researchers in understanding the problem being addressed and in developing products that respond to user needs. Moreover, continuing user involvement throughout the research activity can help ensure that research products will be implemented quickly. Researchers and research managers should work closely with technology transfer staff to identify and communicate with potential users and determine the nature and extent of user needs (see Appendix B for examples of how this is being accomplished in several research programs).

Field tests, demonstrations, and pilot projects: Potential users find these activities helpful in deciding whether to implement new technology; developers find them useful for refining technologies prior to widespread implementation.

Incentives: Incentives such as implementation funds or other financial and technical assistance designed to support early implementation of new technology are favored by implementing agencies. Since early adopters of new technology are often closely watched by others, sufficient funds are needed to complete initial or pilot installations so that early implementation activities do not fail because of a lack of funds.

Senior management support: Successful innovation always requires senior management support and sometimes specific agency management action to organize that support. Experience has shown the value of having a champion for a new technology within the user agency; thus early attention should be given to establishing and supporting champions among the user agency decision makers.

Technical training: Most new technologies require technical training, especially if in-house staff do not have the required expertise. Although user-friendly innovation is a worthy goal of R&D, the problems being addressed often require technologically complex solutions. In many cases, extensive staff training is needed for both implementation and operation if a new technology is to succeed. Such training may also address potential internal resistance to change.

Standards and specifications: Changes to standards and specifications may be needed to accelerate the implementation of certain technologies. Because so much of public-sector procurement is closely governed by standards and specifications, researchers, technology transfer staff, and potential technology users need to identify and work closely with the relevant standards-setting bodies so that if changes to standards and specifications are needed, they can be made quickly and efficiently.

User satisfaction: Technology transfer programs must include careful monitoring of acceptance, adoption, and satisfaction among users of the technologies being promoted. Such information is needed for managing technology transfer activities and for successfully assessing progress toward the goals of these activities.

NOTES

1. State highway agencies report that by implementing products and processes promoted by FHWA, they have achieved an 8:1 savings-to-cost ratio. Agencies also report that such technologies would have taken an average of 3.5 years longer to apply without FHWA assistance (Harder 1995).
2. Until the reorganization, the RTCGs were internal coordinating groups that guided the preparation of FHWA's research and technology program plans and budget proposals. The RTCGs have been eliminated.
3. The study defined a state technology transfer office as a designated office that focuses on accelerating the use of research results throughout a state highway department.
4. The AASHTO Materials Reference Laboratory promotes adherence to existing standards in the testing of construction materials for which standard test protocols and methods have been developed.
5. All the steps leading to implementation can require considerable effort. For example, users must become familiar with the innovation and its capabilities and limitations. Preliminary trials or tests must be undertaken; adaptations needed to fit the innovation to the local environment must be made. Full-scale performance tests may be

needed to ensure that existing operations will continue to function smoothly. Finally, support personnel must be trained to use the innovation.

6. According to Mokyr (1990), risk aversion, leisure preference, and time preference influence the willingness of people to make the effort to innovate.

REFERENCES

ABBREVIATIONS

EPA	Environmental Protection Agency
NCHRP	National Cooperative Highway Research Program
SHRP	Strategic Highway Research Program
TRB	Transportation Research Board

Bikson, T. K., S. A. Law, M. Markovich, and B. T. Harder. 1996. *Facilitating the Implementation of Research Findings: A Summary Report.* NCHRP Report 382, National Research Council, Washington, D.C., 24 pp.

Diewald, W. 1992. Seeking Ways To Accelerate the Implementation of Innovation in Highway Transportation. TR News, No. 163, Nov., 4 pp.

Ducca, F., and E. Weiner. 1996. Upgrading Travel Demand Forecasting Capabilities. *TR News*, No. 186, Sept., pp. 2–6, 39.

EPA. 1991. *Innovative Technology Transfer Workbook: Planning, Process, Practice; Draft Version 1.* Prepared by Technical Resources, Inc., Washington, D.C., Aug.

Farhar, B. C., M. A. Brown, B. L. Mohler, M. Wilde, and F. H. Abel. 1990. *A Planning Framework for Transferring Building Energy Technologies.* Solar Energy Research Institute. U.S. Department of Energy. SERI/TP-260-3729, DE90000347. Washington, D.C., July.

Griffith, R. G. 1990. United States National Report. Appendix J in *Technology Transfer in Selected OECD Countries*, Orlando, Florida.

Harder, B. T. 1995. *Stewardship Report Documenting Benefits of Research Technology Efforts.* Federal Highway Administration. FHWA-SA-96-044. Washington, D.C., Dec.

Mokyr, J. 1990. *The Lever of Riches: Technological Creativity and Economic Progress.* Oxford University Press, New York.

NCHRP. 1989. *Synthesis of Highway Practice 150: Technology Transfer in Selected Highway Agencies.* Washington, D.C., Dec., 44 pp.

NCHRP. 1998. *Research Results Digest 225: Putting Research into Practice: A Synopsis of Successful Strategies and Case Histories.* Washington, D.C., June, 18 pp.

SHRP. 1990. Memorandum on Gap Analysis to Ray Decker, Chairman of the SHRP Steering Committee, from Damian Kulash, SHRP Executive Director. February 21.

TRB. 1998. *Transportation Research Circular 488: Transportation Technology Transfer—A Primer on the State of the Practice*. National Research Council, Washington, D.C., May, 95 pp.

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Proposed Technology Transfer Strategy for FHWA

Among the many issues associated with technology transfer in the highway industry, three will strongly affect the future success of the Federal Highway Administration's (FHWA's) efforts aimed at accelerating the adoption of innovations: (1) the decentralized and largely public-sector nature of the highway industry (see Chapter 3), (2) the contingent[1] nature of technology transfer, and (3) the need for an underlying strategy for FHWA technology transfer activity. Of these the last is an area in which the agency has an opportunity to take action that would enhance the success of its technology transfer efforts.

Although FHWA's organization, process, and materials for technology transfer reflect a good intuitive grasp of information exchange and technology transfer, the agency needs to articulate a strategy for its technology transfer activity—one grounded in empirical data and the experience of agency staff. Such a strategy would assist FHWA in accelerating innovation by focusing on the why of technology transfer, especially in view of the wide range of technology topics to be addressed, and thereby overcome some of the effects of highway indus-

try fragmentation. A strategy would also help avoid repeatedly using the same methods because they "usually work," rather than changing or adapting methods as appropriate for particular circumstances. Moreover, it could help FHWA optimize the use of available methods, respond to unusual situations, and communicate better with the stakeholders involved in the technology transfer process.[2] In addition, a strategy would provide guidance for resource allocation, aid in making choices about specific activities and target groups, help monitor progress to goals, and provide guidance in determining when a specific technology transfer activity should be scaled back or concluded. Regardless of its organizational structure, then, FHWA can accelerate innovation in the highway industry by adopting a specific technology transfer strategy and basing its technology transfer activities on that strategy.

COMPONENTS OF THE PROPOSED STRATEGY

The following sections describe the primary components of the committee's proposed strategy. The strategy is a conceptual framework for FHWA's technology transfer activities. Its four components form a basis for carrying out technology transfer activities and provide a mechanism for managing those activities. While there is evidence that FHWA currently addresses some of these components some of the time, innovation could be accelerated if the agency were to systematically address all of the components all of the time. Adoption of the proposed strategy will require some refinement by FHWA to reflect its recent organizational changes and its relationships with technology users. FHWA also needs to develop specific procedures and practices to carry out the strategy.

Basing Technology Transfer Activities on Knowledge About Research Products and the Technology Users

Much of FHWA's technology base originates in research conducted or sponsored by FHWA, state highway agencies, the National Cooperative Highway Research Program (NCHRP), and the Strategic Highway Research Program (SHRP). Technologies from these sources can be identified through research reports and contact with researchers and technical specialists involved in their development, as well as Trans-

portation Research Board (TRB), professional associations and journals, and the private sector. In addition, through its international technology scans and continuing reviews of emerging technologies in other fields, FHWA is in a position to identify a broad range of technologies that can help meet highway industry needs (see Box 5-1 for more information about international technology scans).

The state highway agencies that build, operate, and maintain much of the nation's highway system are the primary users and purchasers of the products of highway research. Other users include local highway and transportation agencies, contractors, standards-setting bodies, consultants, and equipment manufacturers. Also important are decision makers at the state and local levels who determine whether to fund the implementation of new technologies. Identifying the primary users of a technology and those who can be influential in its implementation is critical to FHWA's technology delivery mission. This information is important because early involvement of potential users in R&D activity—even before a technology is ready to be implemented—has been shown to be a key determinant of successful implementation (see Chapter 4). Such involvement familiarizes users with the products being developed and helps researchers define the problem more clearly. It can also help FHWA identify potential initial implementing agencies that may become strong supporters or champions for specific technologies, as well as assist the agency in selecting appropriate technology transfer methods.

Setting Technology Transfer Priorities

Faced with a wide array of both potential users and research products, FHWA must make critical choices about where and how its limited technology transfer resources will be used. The setting of priorities must precede the selection of technology transfer methods and the initiation of implementation. Setting and revising priorities are part of a continuing process that requires specific guidelines and procedures both to carry out the process and to monitor progress toward goals.[3] Priority-setting guidelines form a framework for decision making. Factors such as the strategic goals of FHWA and the American Association of State Highway and Transportation Officials (AASHTO), expected technology benefits, the extent of user interest, the need for financial incentives,

Box 5-1

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International Technology Scans

Under FHWA's International Technology Scanning Program, foreign technologies that could benefit U.S. highway transportation systems are identified and evaluated (NCHRP 1996). The scans provide a mechanism for examining potentially useful technologies without spending scarce research funds to recreate advances already made by other countries. The program is undertaken cooperatively among AASHTO and its Select Committee on International Activities, NCHRP, the private sector, and academia. Once priority topics have been determined, FHWA forms teams of specialists that visit countries in which significant advances and innovations have been achieved in technology, management practices, organizational structure, program delivery, and financing.

As an example, in June and July 1995, the Technology Scanning Review of European Bridge Structures was conducted under the auspices of FHWA's International Outreach Program and NCHRP in cooperation with the American Consulting Engineers Council, the American Institute of Steel Construction, the American Road and Transportation Builders Association, the Associated General Contractors of America, and the Portland Cement Association. Personnel from FHWA and AASHTO member departments, as well as individuals from the private sector and academia, traveled to five European countries to review bridge practices and identify technologies and practices that merit further consideration for potential domestic application. The review team was able to gather considerable information on bridge practices in the following areas: policy, administration, and management; design philosophies and methods; materials; production and fabrication; bridge management systems; and maintenance. The team prepared preliminary findings on the potential technical, economic, and environmental advantages of the European practices. The team also prepared 18 recommendations that merit consideration by public and private agencies.

potential product commercialization, and opportunities for private-sector partnering form the basis for setting priorities (see Box 5-2). The responsibility for setting of technology transfer priorities in the restructured FHWA is at present unclear. Nevertheless, FHWA should establish a formal process for priority setting that includes the proposing of priorities, means of obtaining input from representatives of potential users, and executive review of the proposed priorities.

Choosing Appropriate Technology Transfer Methods

Technology transfer is a complex process for which no standard methodology is available; the process involves a wide range of variables that cannot easily be identified or accounted for (Eveland and Tornatzky 1990). Yet knowledge of the research product and its users is always an important first step. The nature of the technology—as indicated by its

Box 5-2

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Bases for Priority Setting

Many potential strategic directions or choices can form the basis for setting priorities in technology transfer. These include promoting research products with the highest estimated ratio of user benefits to technology transfer cost; emphasizing delivery of products to users that are most receptive to innovation or have the greatest likelihood of implementation success; focusing on products for which highway industry partners can be found; and emphasizing products that match most closely FHWA's strategic goals, as well as national and state goals.

Technology transfer can be focused on specific steps within the innovation process while effort on other steps is minimized, depending on the research products and users involved. Another alternative is to focus the technology transfer effort on those who decide which technologies will be implemented in state and local highway agencies.

range of potential applicability, degree of hardware dependence, and adaptability—affects technology transfer choices, as do user and user organization characteristics. FHWA's program goals, incentives, and organizational structure for performing technology transfer and providing technical assistance also affect appropriate choices. Understanding what has worked in the past in specific technology areas is helpful as well. And early involvement of potential users helps in the selection of appropriate technology transfer tools.

Tactics and tools can be chosen, adapted, and designed to emphasize specific questions or assistance issues related to implementation. For example, consider a research product related to bridge construction that could reduce the susceptibility of bridge decks to salt corrosion. Technology transfer for such a product would require direct contact with state bridge engineers because they make the critical choices on bridge design issues. If the product were the result of a lengthy research and field testing and demonstration effort to reduce salt corrosion, state bridge engineers would be likely to be aware of the nature, value, and cost of the product and might have been involved as reviewers or participants in the work. Such a situation might require tactics and tools focused on details of technology implementation.

If, however, the research product stemmed from an unexpected breakthrough in another research area or industry and needed further testing and evaluation prior to implementation, another set of tactics and tools might be required. For example, considerable introductory and explanatory material would have to be provided for breakthrough technologies. State bridge engineers would still need to be directly involved. In this latter case, however, it might be useful to initiate involvement with a small number of engineers known for their interest in innovation and concerns about salt corrosion. For example, FHWA could form a technical working group to help develop appropriate tests and demonstrations that would address the engineers' primary concerns.

Measuring the Effectiveness of Technology Transfer Efforts

The purpose of measuring the status and performance of technology transfer efforts is twofold: to determine whether those efforts are making progress toward the goal of widespread implementation, and to

determine and document which methods work best for specific product–customer combinations. Such measurements are necessary to achieve continuous improvement in the overall technology transfer program and to help satisfy agency performance requirements. In addition, they provide a basis for documenting accomplishments within the R&D program.[4]

Since implementation is the primary goal of technology transfer efforts, the extent to which the user community implements research products is a key measure of the success of those efforts. However, successful implementation is generally measured by operational success, and limited time and resources are available to track research ideas to implementation. As a consequence, there are no standardized tools available for the purpose. One approach would be to record the number of highway agencies that adopted a technology, for example, how many highway agencies use the Superpave mix design. Using the same example, another measure could be the annual proportion of Superpave mix design contracted for by a highway agency. Other measures could address the broader implications of implementation in terms of FHWA's strategic goals, such as lives saved and injuries reduced, or cost or time savings.

An important issue associated with performance measurement is the fact that technology implementation is not an end in itself (Eveland and Tornatzky 1990). Measuring performance involves determining what successful implementation of specific research products means when there are direct and indirect as well as long- and short-term consequences. Successful implementation might mean that design standards are changed to permit use of a product in some or all cases, or that an innovative design is used in a majority of states. Or, as in the case of Superpave, it might mean that a predetermined percentage of highway pavement is designed and constructed using the Superpave mix design. Since implementation is the primary aim of innovation, adoption of a technology is a useful surrogate for technology transfer. Some form of adoption rate can be used as part of an overall evaluation of the technology transfer effort.

Measuring effectiveness should not be viewed as the final step in the technology transfer process; rather, innovation is a continuous process that involves many feedback loops. For a mission agency such as

FHWA, it is also a continuous learning process. While technology transfer can help achieve a high level of adoption for a research product, it can also provide information that leads to changing or concluding a specific technology transfer effort because the potential benefits cannot justify the resources being expended. Such information and the decisions it supports are as important to successful technology transfer as is widespread implementation. Better-informed decision making enables efficient resource allocation and supports the overall goal of accelerating innovation.

ADDRESSING TECHNOLOGY TRANSFER IN A RESTRUCTURED FHWA

FHWA's recent reorganization created a new operating environment for technology transfer. As noted in Chapter 1, effective October 1, 1998, FHWA closed its nine regional offices and established four technical resource centers to support the state division offices. The resource centers are located in Atlanta, Boston, Olympia Fields (Illinois), and San Francisco. The centers support the state-level division offices in their primary role of program delivery by providing leadership on strategic initiatives and expert assistance on technical process and program issues, training, technology transfer, intermodal and interagency coordination, legal services, and civil rights. Each resource center is assigned a group of states within a geographic area, but specific technical expertise is shared among resource centers and division offices as needed.

Also effective October 1, 1998, FHWA restructured its headquarters office, which now has five core business units: infrastructure, planning and environment, operations, motor carrier and highway safety, and federal lands highway. Eight service business units—policy; administration; research, development, and technology; professional development; corporate management; civil rights; public affairs; and legal counsel—support and coordinate across the business units. This matrix structure is designed to enable the agency to create integrated product teams as needed, with responsibility and accountability for the delivery of specific technologies, programs, or other products.

The Office of Technology Applications (OTA), which was the focus of FHWA's technology transfer activities, has been eliminated. Each of the five core business units and the Office of Research, Development, and Technology (ORDT) are now responsible for technology transfer activities. These groups are to work closely with and support the four new resource centers in their technology transfer efforts.

FHWA's reorganization poses significant challenges and opportunities for the agency's technology transfer efforts. Technology transfer is now a staff function in each of the five core business units and ORDT. Although this arrangement can facilitate a closer connection between the individual business units and the potential users of technology, it also spreads FHWA's technology transfer expertise across many offices. The risk is that FHWA's technology transfer competence will be dissipated, and the advantages of locating the agency's technology transfer capability in a single management unit, such as ease of monitoring agencywide technology transfer activities and evaluating what does and does not work, will be lost.

In addition, the FHWA reorganization plan does not articulate how FHWA will manage the flow of information between researchers and technology transfer specialists in the core business units, ORDT, the four resource centers, and the division offices. Moreover, FHWA has not identified which of its offices has agencywide management responsibilities related to technology transfer, and responsibility for several important management requirements remains unassigned.[5] Questions that need to be resolved include how a core business unit will learn from the technology transfer successes, or perhaps even failures, of another core business unit; who will be responsible for maintaining technology transfer communication channels among the core business units; and how technology transfer specialists from outside the agency (i.e., from state highway agencies, universities, and LTAP centers) will be included in FHWA's technology transfer process. More specifically, the management requirements that need to be addressed in the FHWA reorganization include the following:

- Authority and responsibility for setting agencywide technology transfer priorities;
- Coordination of technology transfer activities across the core business units;

• Maintenance of internal expertise in the process of technology transfer;

• Identification of what works in the long run, in terms of both new technologies and technology transfer methods, for research products and FHWA's customers; and

• The means for monitoring and measuring the performance of technology transfer and progress toward goals.

NOTES

1. The committee uses the term "contingent" to denote the dependence of technology transfer activity on many interrelated factors, some of which are unpredictable. These include, for example, the variety and complexity of the technologies and technology users, the differences in the way specific technologies are implemented, and variations in implementation time frames. See also Downs and Mohr (1976).
2. Rogers (1962) describes some implementation pitfalls in the highway industry.
3. The setting of technology transfer priorities should also be based on previous decisions about research priorities within FHWA's research management process.
4. Performance measurement is a requirement of the Government Performance and Results Act of 1993. FHWA recently began efforts to set goals and measure performance in its R&D program (FHWA 1998).
5. Benchmarking of the management and operation of FHWA's technology transfer activities against those of agencies and organizations that rely on other organizations to implement their research results could be useful.

REFERENCES

ABBREVIATIONS

FHWA	Federal Highway Administration
NCHRP	National Cooperative Highway Research Program

Downs, Jr., G., and L. Mohr. 1976. Conceptual Issues in the Study of Innovations. *Administrative Science Quarterly.* Vol. 21, pp. 700–714.

Eveland, J. D. and L. G. Tornatzky. 1990. The Deployment of Technology. Pp. 117-147 in *The Processes of Technological Innovation* (L. G. Tornatzky and M. Fleischer, eds.). Lexington Books. Cambridge, Mass.

FHWA. 1998. *Setting Goals and Measuring Performance for Transportation Research and Technology Programs.* Washington, D.C., Jan.

NCHRP. 1996. *NCHRP Report 381: Report on the 1995 Scanning Review of European Bridge Structures.* Washington, D.C., 36 pp.

Rogers, E. M. 1962. *Diffusion of Innovations.* New York, The Free Press of Glencoe.

6

Summary and Recommendations

Although technology transfer in the highway industry is complex and requires considerable effort from all participants, the process is essential to accelerated innovation and to the Federal Highway Administration's (FHWA's) technology delivery mission. The committee's proposed strategy for future FHWA technology transfer activities as described in the previous chapter reflects recognition of the complexity of technology, as well as the fragmented nature of the highway industry and the unpredictable nature of technology transfer. The proposed strategy serves as straightforward guidance for directing FHWA's limited resources at industry needs in support of enhancing the nation's highway system. In addition, the effectiveness of various technology transfer tactics and tools should be examined on a regular basis to determine their effectiveness. The final component of the proposed strategy includes gathering information that should be useful in measuring performance in specific technology transfer activities. This information can also be used to assess the overall effectiveness of technology transfer and to make future resource allocation decisions.

FHWA's recent reorganization included the elimination of the Office of Technology Applications (OTA), formerly the focus for FHWA technology transfer activity, and the creation of new technology transfer groups within each of the five new core business units and the research, development, and technology service unit. However, FHWA did not assign agencywide management responsibility for technology transfer activities to any single office. Technology transfer is too important to FHWA's technology delivery mission for the agency to neglect key management requirements of the process, such as setting agencywide technology transfer priorities; coordinating technology transfer activities across the core business units; maintaining internal expertise in the process; and determining what works in the long run, in terms of both new technologies and technology transfer methods, for new research products and FHWA's customers. Failure to address these management requirements could hinder FHWA's ability to fulfill its technology delivery mission. Moreover, if overall management responsibility for technology transfer is not assigned, FHWA will be unable to track technology transfer performance and measure progress toward goals. In this context, the committee offers the following recommendations for strengthening FHWA's technology transfer program.

FHWA should assign agencywide management responsibility for technology transfer to one of its headquarters offices. That office should then prepare a management plan for future FHWA technology transfer activities. The functions recommended here would differ significantly from those formerly carried out by OTA. OTA's mission was to implement new technology. This recommendation is for an office with the mission of providing a strategic focus at the corporate level for technology transfer activities throughout the core business units. The recommended plan should describe how the office would coordinate future FHWA technology transfer activities across the core business units; the Research, Development, and Technology service unit; and the field organization. Specific items that should be addressed in the plan include how FHWA will set agencywide technology transfer priorities, monitor individual technology transfer activities, and measure performance so it can learn what does and does not work.

FHWA's technology transfer management plan should include a strategy for the agency's technology transfer activities. This strategy

should incorporate the key characteristics of successful technology transfer and the four strategy components outlined in Chapter 5. The committee believes FHWA needs such a fundamental strategy if it is to carry out its stated mission of delivering technology to the highway industry with the limited resources available.

Finally, FHWA needs to develop strong partnerships with those who use and implement highway technologies, as well as the decision makers who are responsible for funding related to innovation. The committee believes involvement of the user community is critical to the success of both R&D and technology transfer activities, and recognizes that FHWA has initiated efforts to identify and engage its technology partners. The agency should continue these efforts and bring its partners into the research phase of its technology development activities as early as possible to help define and direct the research effort. FHWA's partners, particularly the states, are much closer to the operating environment in which technology must succeed and are essential to its successful implementation.

Appendix A

Research and Technology Delivery Functions of FHWA's Five Core Business Units and the Office of Research, Development, and Technology

The FHWA headquarters organization consists of five core business units (CBUs): Planning and Environment; Infrastructure; Federal Lands Highway; Operations; and Motor Carrier and Highway Safety; as well as eight service business units. The Statement of Mission and Functions for each of the five CBUs and for the Research, Development, and Technology service business unit (SBU) includes a statement for the research and technology delivery function. These statements are presented below.

Unit Name	Function Statement for Research and Technology Delivery
Planning and Environment	Identifies research and technology transfer in the areas of planning, environment, and realty (with the support of the Research, Development, and Technology SBU. In partnership with the resource centers, designs and implements programs that deploy new models, practices, and technologies to continuously advance the state of the best

	practice industrywide. Partners with the resource centers, other CBUs, and SBUs in developing and evaluating training courses in planning and environment. Develops technical and guidance materials and in some cases provides instructors.
Infrastructure	In cooperation with divisions, resource centers, and other CBUs, leads the development of near-term research, development, and technology (RD&T) program plans (roadmaps) in the areas of highway construction and physical maintenance, pavements, and structures. Assists in the marketing and dissemination of information on emerging technology resulting from such RD&T activities. In partnership with the resource centers, designs and implements programs that deploy new technologies to continuously advance the state of the best practice industrywide. Partners with the resource centers and other CBUs in developing and evaluating training courses related to highway, pavement, and bridge engineering and asset management. Develops technical documents and guidance materials related to that training, and in some cases provides instructors.
Federal Lands Highway	Promotes the development of applied research and technology applicable to transportation serving federal lands. Provides technology delivery and related information and knowledge sharing to federal agencies, Indian Tribal Governments, and FHWA's resource centers to promote innovations and best practices.
Operations	Leads the development of U.S. DOT-wide, near-term RD&T program plans for ITS, and agencywide plans for transportation operation and management and freight. Ensures that technology investments in these areas are linked to the U.S. DOT and agency strategic and performance plans. In partnership with the resource centers, designs and implements programs that deploy new technologies and training to continuously advance the state of the best practice industrywide, thereby improving the performance of the surface transportation system.
Motor Carrier and Highway Safety	Leads the development and implementation of research and technology studies, and activities for motor carrier safety and commercial motor vehicle and driver safety.

	Conducts research in support of the motor carrier safety regulatory program. Works in concert with other government agencies, foreign government agencies, industry, and labor to continuously advance the state of the best practice nationwide to improve the safety performance of the highway transportation system.
Research, Development, and Technology	Supports the CBUs in the development of near-term RD&T program plans. Supports the CBUs and the resource centers in the development and delivery of new technologies, and assists in the design and implementation of feedback systems for evaluating the effectiveness of new technologies.

SOURCE: FHWA (1999).

REFERENCE

ABBREVIATION
FHWA Federal Highway Administration

FHWA. 1999. *Department of Transportation Organization Manual.* DOT-110063B. U.S. Department of Transportation, Feb.

Appendix B

Examples of User Involvement To Promote Technology Transfer

Early user involvement has been identified in several studies as being essential to successful technology transfer (TRB 1998). This appendix presents three examples of successful user involvement that have helped achieve innovation in the public sector. The first section describes the early involvement of potential users in the National Cooperative Highway Research Program (NCHRP). The second illustrates how the state of Virginia organizes its R&D planning and technology transfer efforts to encourage the participation of the potential end-users at the earliest planning stages. (Note that other states, for example, California, New York, and Texas, have established other institutional mechanisms that have proven successful in facilitating the delivery of innovative highway technology.) The final section describes how the Construction Industry Institute (CII) addresses the issue of putting its research products to use.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP is a continuing program of highway research administered by professional staff of the Transportation Research Board (TRB). Established in 1962, it is sponsored by the member departments of the American Association of State Highway and Transportation Officials (AASHTO) in cooperation with the Federal Highway Administration (FHWA). To fund the program, each state contributes a portion of its federal-aid State Planning and Research (SP&R) funds. These funds presently form a cooperative pool of about $22 million annually.

AASHTO and FHWA work together on the formulation, approval, and acceptance of each annual NCHRP research program, primarily through the AASHTO Select Committee on Research (SCOR), which includes FHWA as a member. The emphasis is on projects that will provide solutions to well-defined problems and can be implemented quickly by the state highway agencies. Once a project has been approved, a panel of technically knowledgeable individuals is selected to determine its purpose and scope and to provide guidance and counsel throughout the course of the project. About half the panel membership consists of state highway and transportation department personnel. NCHRP staff and the project panels work together to ensure a balance between research objectives and the needs of highway practitioners.

Panel members become important links between the research effort and the eventual application of the project results. A major reason for NCHRP's success has been its ability to involve highway practitioners in the research from beginning to end. NCHRP research recommendations have high credibility with AASHTO committees because the members know the project was closely monitored, and the final report was reviewed by a panel that included experienced practitioners, among them members of relevant AASHTO committees. NCHRP uses publications and widespread dissemination of its reports to further the transfer of the technologies involved.

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

The Virginia Transportation Research Council is the R&D arm of the Virginia Department of Transportation. In keeping with its premise that the key to successful R&D is implementation, the Council involves many of the potential users of its R&D products in program decision making. The council has 13 research advisory committees, each with approximately 20 members. Committee members include representatives from the Virginia Department of Transportation, local government, universities, and the transportation industry.

Each committee meets at least once a year to provide research ideas for the next year's program and an assessment of the current R&D products. The committees serve as an outside source of potential R&D topics, and the committee members become stakeholders in the R&D process, with a strong interest in the research outcomes. Indeed, committee members are in a position to implement the results of the R&D even before the final research reports have been published.

CONSTRUCTION INDUSTRY INSTITUTE

CII is a research organization whose mission is to improve the quality and cost-effectiveness of planning and delivery systems for capital projects in support of U.S. industry. CII represents a consortium of about 80 facility owners, construction and architectural/engineering companies, and government organizations that focus on the construction needs of the process industries and the light industrial/general building sector. In addition to annual dues, membership in CII requires participation by senior company personnel on the Institute's Board of Advisors and participation of experienced company personnel on the Institute's committees, councils, and teams. The typical annual investment for a member organization is approximately $250,000. CII members are also expected to share nonproprietary project information with CII research and advisory teams, as appropriate.

Ad hoc research teams oversee individual research projects that have been designated by the Board of Advisors for future study. These research teams take a general scope of work prepared by the Board of Advisors and focus on specific details, ultimately developing research

proposals that are presented to the Board for funding. Once funding has been approved, the research team spends 1 to 3 years conducting the research and reporting the results.

The Institute's pooled-fund, member-sponsored research program is focused on research products that are ready for implementation and provide a payoff for the member organizations. CII's Implementation Strategy Committee explores industrywide implementation opportunities and develops strategies designed to overcome barriers to implementation and increase its rate and extent. Mechanisms used to promote implementation include research reports and publications, implementation support manuals, multimedia presentations, education modules, workshops and seminars, and pilot projects. CII strives for research products that are convenient to implement. While individual companies are responsible for implementation, the Institute provides extensive support. The CII implementation model is shown in Figure B-1.

Figure B-1 Construction Industry Institute implementation model.

REFERENCE

ABBREVIATION
TRB Transportation Research Board

TRB. 1998. *Transportation Research Circular 488: Transportation Technology Transfer—A Primer on the State of the Practice*. National Research Council, Washington, D.C., May, 95 pp.

Appendix C

Descriptions of Selected FHWA Technology Transfer Areas and Related Technology Transfer Activities

Technology Area	Technology Transfer Activities
Scour Monitoring and Instrumentation Products or processes that promote the prevention of hydraulic-related failures of highway bridges and provide countermeasures for the effects of stream stability, scour, erosion, and sediment deposits.	• NHI course: Stream Stability and Scour at Highway Structures • Demonstration Project 80: Underwater Inspection of Bridges • FHWA Hydraulic Engineering Circulars HEC-18 and HEC-20 • WSPRO Water-Surface Profiles: Bridge Waterways Analysis Model • FHWA Technical Advisory T5140.20: *Scour at Bridges*

Geotextile Engineering Applications Products or processes that incorporate the use of geotextiles in highway design, construction/rehabilitation, and maintenance applications, as well as geotextile concepts for earthfill and embankment projects.	• NHI course: Geotextile Engineering Workshop • Demonstration Project 82: Ground Modification Techniques • *Geotextile Engineering Manual* (1986) • *Geotextile Specifications for Highway Applications* (1989)
Pavement Management Systems Products or processes that constitute a comprehensive pavement management system (PMS) as required by ISTEA. This technology area also incorporates the effects of having implemented a comprehensive PMS on such items as information availability and reliability; decision making for maintenance, rehabilitation, and reconstruction of pavements, and prioritization, scheduling, and funding for those activities; and computerized tools to accomplish the required analysis.	• NHI courses: Pavement Management Principles and Practices; Techniques for Pavement Rehabilitation; and PMS Within State Agencies; also pavement management conferences • Demonstration Project 61: Pavement Management-Rehabilitation Programming (1982) • FHWA PMS technical specialists • Pavement condition measuring manuals and proceedings of pavement management workshops • Application Project 68: Pavement Management Systems (college course)

Bridge Management Systems Products or processes that constitute a comprehensive bridge management system (BMS), required by ISTEA. This technology area also incorporates the effects of having implemented a comprehensive BMS on such items as information availability and reliability; decision making for maintenance, rehabilitation, and reconstruction of bridges, and prioritization, scheduling, and funding for those activities; and the computerized tools needed to accomplish the required analysis.	• BMS and PONTIS workshops • Demonstration Project 71: Bridge Management Systems • FHWA BMS technical specialists • BMS manuals and workshop materials • PONTIS computer programs
Protective Coatings Processes that encompass environmentally acceptable coatings and corrosion-control alternatives to effectively protect highway structures and components; examples include cost-effective corrosion methods and control, protective coating systems, bridge paint removal and containment/recovery, and life extension of structures protected by lead-containing paint systems.	• NHI course: portions of Bridge Painting Inspection • *Coatings Guide for In-Service Steel Highway Bridges, Corrosion Control of Highway Structural Components by the Application of Powder Coatings*, and *Performance of Alternate Coatings in the Environment* • Test and Evaluation Project #4: Protective Coatings

Seismic Design of Highway Bridges Products or processes that contribute to improved earthquake protection of new and existing bridges. This technology encompasses the FHWA program that sponsored R&D building upon the State of California's earthquake design criteria for bridges, and culminating in a comprehensive guide specification adopted by AASHTO in 1982. Items included in this technology area are seismic design of bridges, foundations, and substructures, and retrofitting of existing structures.	• NHI course: Seismic Design of Highway Bridges • Regional meeting and workshops on ISTEA as it affected bridge programs • *Seismic Design and Retrofit Manual for Highway Bridges* • Partnership with AASHTO to modify the AASHTO specifications
Work Zone Traffic Control Products or processes that incorporate all aspects of work zone traffic management and control, such as design, installation, and maintenance of controls in construction, maintenance, and utility operations; traffic control planning and monitoring; traffic control devices; and legal and other operational aspects.	• NHI courses: Design and Operation of Work Zone Traffic Control and Integrated Work Zone Traffic Control Trainer/Advisor (interactive videodisc course) • *Work Zone Traffic Control Information Catalog* and reports on such topics as planning and scheduling, improved concepts, speed control, and work zone management syntheses

Bridge Inspection Techniques Products or processes that incorporate all aspects of bridge inspection, such as inspection concepts, safety, inspection documentation, and inspection and evaluation of bridge decks, sub- and superstructures, and fracture-critical bridge members; and solutions provided by appropriate inspection methods to prevent material distress and ultimately failure.	• NHI courses: Engineering Concepts for Bridge Inspectors, Safety Inspection of In-Service Bridges, and Inspection of Fracture Critical Bridge Members • Demonstration Project 80: Bridge Inspection Techniques and Equipment (1989), now titled Underwater Inspection of Bridges • *Bridge Inspector's Training Manual 90* • Application activities, such as bridge inspection examination to qualify state bridge inspectors
Highway Drainage Design Products or processes that incorporate guidance and procedures for highway drainage design, such as hydraulic analysis, culvert design, roadway drainage design, energy dissipater design, and channel design, including associated computer programs for hydraulic and hydrologic design.	• NHI courses: Culvert Design and HYDRAIN—Integrated Drainage Design • Demonstration Project 73: Highway Drainage Design (1986) • Hydraulic Engineering Circular 12: *Roadway Drainage Design* (1984); Hydraulic Design Series 5: *Culvert Design* (1985) • HYDRAIN computer program • Application activities, such as providing states with portable hydraulic flume equipment

Driven Piles/Pile Foundations Products or processes that encompass design and construction of all aspects of driven pile technology, such as subsurface investigation, pile types, static design and analysis and data interpretation, specifications and contracting, construction monitoring, load testing, and driven pile installation equipment and accessories.	• Driven Pile Foundations Workshop, Pile Group Prediction Symposium • Demonstration Project 66: Design and Construction of Driven Pile Foundations • *Handbook on Design of Piles and Drilled Shafts Under Lateral Load* and *Performance of Pile Driving Systems: Inspection Manual* • Computer programs for static pile analysis, approach embankment settlement, lateral load analysis, and driving system evaluation
Avoidance/Handling of Construction Contract Claims Products or processes that minimize future construction contract claims. This area also incorporates a systematic approach to reducing claims and valuing appropriate documents, and documentation that enables claims avoidance, effective negotiation and dispute resolution, reduction of legal actions, and increased quality of construction performance.	• NHI course: Avoidance and Handling of Construction Contract Claims • *Guidelines for the Administration of Highway Construction Claims*, and *State Laws and Regulations Governing Settlement of Highway Construction Contracts Claims and Claim Disputes*

Computer Models for Traffic Engineering and Operations Products or processes that encompass the broad range of computerized tools used for traffic engineering and operations. This technology area also incorporates the impacts of computer systems on data analysis and decision making; the value of increasingly more accurate data and its availability; the significantly enhanced ability to perform traffic signal timing optimization; and other traffic engineering or operations applications, including such items as developing incident management alternatives.	• NHI course: TRAF-NETSIM Training Course • Training courses, workshops, and conferences on highway applications of microcomputers • Demonstration Project 62: Microcomputers in Traffic Engineering • *Traffic Models Handbook* (1981) and update; user guides for computer programs TRAF-NETSIM, CORFLO, FRESIM, and others; and an expert system for incident management • Applications activities, such as Traffic Software Users Group, strategic alliance with McTrans, distributor/clearinghouse for traffic engineering and operations models/software

SOURCE: Harder (1995).

REFERENCE

Harder, B. T. 1995. *Stewardship Report Documenting Benefits of Research Technology Efforts.* FHWA-SA-96-044. Federal Highway Administration, U.S. Department of Transportation, Dec.

Study Committee Biographical Information

C. Michael Walton, *Chairman,* is professor of civil engineering and holds the Ernest H. Cockrell Centennial Chair in Engineering at the University of Texas at Austin. In addition, he has a joint academic appointment in the Lyndon B. Johnson School of Public Affairs. He is a founding member of ITS America, chairing its Technical Coordinating Council and serving on its board of directors. He is a fellow of the American Society of Civil Engineers (ASCE) and the Institute of Transportation Engineers (ITE), and a member of the National Academy of Engineering (NAE), the Institute for Operations Research and the Management Sciences, Urban Land Institute, Society of American Military Engineers, Society of Automotive Engineers, Council of University Transportation Centers, and National Society of Professional Engineers. He is a past chair of TRB's Executive Committee and on the board of directors of both the International Road Federation and the International Road Educational Foundation.

Allan L. Abbott is the director of public works for the city of Lincoln, Nebraska. Previously he was with Wilbur Smith Associates, and was the director and state engineer of the Nebraska Department of Roads from 1991 to 1999. He worked for the Illinois Division of Highways from 1961 to 1991. He served as chairman of the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Research and is currently chairman of the TRB Long-Term Pavement Performance Committee. He has a bachelor's degree from the University of Illinois and a master's from Sangamon State University.

Joel D. Anderson has been the executive vice president of the California Trucking Association (CTA) since 1992. He joined the association in 1977 as a regulatory specialist. Previously he served as assistant executive vice president of industry economic development and was responsible for the association's research, educational, and regulatory activities. Before joining CTA he was an economist for the California Public Util-

ities Commission. He has a bachelor's degree from the University of California at Los Angeles.

Dwight M. Bower is director of the Idaho Transportation Department. Before his appointment in 1993, he worked for the Colorado Department of Transportation (DOT) starting in 1957. A graduate of the University of Colorado, he has served on the TRB Executive Committee as well as several TRB, AASHTO, and National Cooperative Highway Research Program (NCHRP) committees. He was co-chairman of the National Quality Initiative in 1992 and has chaired the TRB Task Force on Innovative Contracting Practices. He currently serves on the AASHTO Board of Directors and is chairman of its Standing Committee on Research.

Richard P. Braun, consultant, founded the University of Minnesota's Center for Transportation Studies, serving as director from its inception until his retirement. He was the commissioner of the Minnesota DOT from 1979 to 1986 and president of AASHTO in 1985. Previously he worked more than 30 years in different posts with the Minnesota Department of Highways. He also served as a vice president and principal associate with Barton-Aschman Associates, Inc., directing projects in the Twin Cities Office. He served on the TRB Executive Committee and on the Strategic Highway Research Program (SHRP) Executive Committee and as chairman of the Twin Cities Area Metropolitan Airports Commission.

John E. Breen holds the Nasser I. Al-Rashid Chair in Civil Engineering at the University of Texas at Austin. From 1962 to 1985 he was the director of the Phil M. Ferguson Structural Engineering Laboratory at the university. Elected to NAE in 1976, he is an honorary member of the American Concrete Institute (ACI) and has served as chair of the ACI Building Code group. He is a fellow of ASCE and a member of the International Association for Bridge and Structural Engineering.

Forrest M. Council is currently a staff associate at the University of North Carolina Highway Safety Research Center, which he served as director from 1993 through July 1999. He also is associated with Bellomo-McGee, Inc. He is a member of TRB standing committees on Roadside Safety Features and Traffic Records and Accident Analysis,

and of the NCHRP Oversight Panel for Project 17-11, "Determination of Safe/Cost-Effective Roadside Slopes and Associated Clear Distances." He chaired the Committee on Methodology for Evaluating Highway Improvements. He is a past president of the National Child Passenger Safety Association and a member of the Association for the Advancement of Automotive Medicine. Twice he has received TRB's D. Grant Mickle Award for best paper in the area of operations, safety, and maintenance. Previously he served on the TRB Committee for the Study of Relationships Between Vehicle Configurations and Highway Design and the Committee for Guidance on Setting and Enforcing Speed Limits.

Frank L. Danchetz is the chief engineer for the Georgia DOT. A graduate of Georgia Institute of Technology, he has been with the department since 1971. He is responsible for highway planning, operations, and maintenance throughout the state. He currently serves on the AASHTO Standing Committee on Research and is the vice chairman of the AASHTO Standing Committee on Highways; he is the chairman of the AASHTO National Transportation Product Evaluation Program.

Henry (Hank) E. Dittmar is president of the Great American Station Foundation. Previously he was campaign director of the Surface Transportation Policy Project, a coalition of environmental, consumer, and planning groups that focuses on the policy implications of transportation programs. He has managed a bus line and an urban airport and has worked for the Metropolitan Transportation Commission in Oakland. He is active on several TRB committees, including the Committee on Intergovernmental Relations and Policy.

Irwin Feller is director of the Institute for Policy Research and Evaluation and professor of economics at the Pennsylvania State University. He is a specialist in technology transfer and innovation processes, with particular emphasis on state and local government and university-industry-government research-and-development partnerships. He has authored numerous publications addressing the issues of technology transfer and innovation in the public sector. He is a member of the American Economic Association, the American Association for the Advancement of Science, and the Association for Public Policy Analysis and Management.

Nancy D. Fitzroy is retired from the General Electric Company's Corporate Research and Development Division. A chemical engineer whose specialty is heat transfer, she was elected to NAE in 1995. She is a fellow and a past president of the American Society of Mechanical Engineering International and an honorary fellow of the Institution of Mechanical Engineers (UK). She holds honorary doctorates from the New Jersey Institute of Technology and Rensselaer Polytechnic Institute.

Larry R. Goode is the director of transportation planning, policy, and finance at the Institute for Transportation Research and Education, North Carolina State University. He previously served as state highway administrator for the North Carolina DOT, where he began work in 1972. He serves on several committees of ITE and AASHTO and on several NCHRP project panels. He is a registered professional engineer in North Carolina and Virginia.

Jack Kay currently serves as executive transportation adviser to SAIC, an employee-owned technology company with a specialty practice in transportation and transportation research. He previously served as president of JHK & Associates, a national transportation consulting firm acquired by SAIC. He has served as an adviser to the World Bank on transportation planning and traffic engineering in many developing countries. He was chair of the board of directors of ITS America, is a fellow of ITE, and chaired the ITE Intelligent Vehicle-Highway System Advisory Committee from 1990 to 1993.

Joe P. Mahoney is the Inger and Allan Osberg Professor of Civil Engineering at the University of Washington. A specialist in pavement and materials engineering, he has also served as the director of the University's Transportation and Construction Engineering Program and as the director of the Washington State Transportation Center. He recently worked with the Council for Scientific and Industrial Research in Pretoria, South Africa, to assess the applicability of its pavement research results to U.S. conditions. He served on the SHRP Pavement Performance Advisory Committee and the SHRP-IDEA Advisory Committee.

Michael M. Ryan is the deputy secretary for highway administration of the Pennsylvania DOT. A graduate of the University of Pennsylvania and Bucknell University, he has been a member of the department since 1968. He is responsible for all design, construction, and maintenance activities in the state. Previously he served as chief engineer, district engineer, and director of the Bureau of Maintenance.

Thomas A. (Tommy) Smith is a transportation consultant in Orlando, Florida. He was previously the vice president of T.Y. Lin International's Michigan operation, based in Detroit, where he oversaw business development and managed the structural and civil engineering firm's office. Before that he served for 10 years as the deputy commissioner and chief traffic engineer for the Chicago DOT. He is a graduate of the University of Michigan and Roosevelt University.

David Spivey is executive vice president of the Asphalt Paving Association of Washington, Inc. He has been involved in asphalt paving construction since 1971; he also has served as a state director of the National Asphalt Pavement Association. Previously he was vice president of CSR Associated, Inc., an international construction and building materials company based in Washington.

Dale F. Stein is president emeritus of Michigan Technological University, where he also served on the faculties of the Department of Metallurgical Engineering and the Department of Mining Engineering. He is past president of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers and was named a fellow in 1979. He also is a fellow of the American Society of Metals. He was elected to NAE in 1986.

David K. Willis is the president and CEO of the AAA Foundation for Traffic Safety. He has also served as director of the ATA Foundation, Inc., and as the director of policy research for the Motor Vehicle Manufacturers Association. He is a member of TRB's Committee on Safety and Mobility of Older Drivers and a member of the board of directors of the National Sleep Foundation.

The Transportation Research Board is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research results. The Board's varied activities annually engage more than 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

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NATIONAL ACADEMY PRESS
ISBN 0-309-7102-X