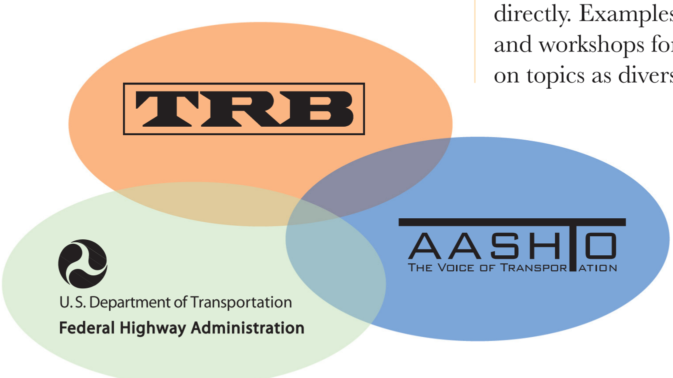
National Partners Drive NCHRP Implementation

In 1962, the forerunners of the Transportation Research Board, the American Association of State Highway and Transportation Officials, and the Federal Highway Administration jointly founded the National Cooperative Highway Research Program. More than 50 years later, these partners are working together even more closely to accelerate the use of NCHRP research among all levels of government.

Realizing the States' Investment

NCHRP is a program of the states, by the states, and for the states. Funded by federal state planning and research dollars, the program helps solve high-priority problems of shared concern among DOTs. NCHRP necessarily focuses its efforts on applied research, but as NCHRP Manager Chris Hedges notes, the research findings are just a step toward the ultimate goal. "The investment in NCHRP is not fully realized until the research is implemented," he says.



TRB, AASHTO, and FHWA work closely and cooperatively to help implement NCHRP research findings.

Many aspects of the program are specifically designed to foster implementation, from the start of a research project (all project proposals must include an implementation plan) to its conclusion (NCHRP's reporting and dissemination efforts have evolved with the needs of transportation managers and practitioners in mind).

> "The investment in NCHRP is not fully realized until the research is implemented."

However, even with the clear goal of implementation, converting research results into practice is a large undertaking, and it requires dedicated effort from multiple fronts. The national partners involved with NCHRP's administration (TRB), guidance (the state DOTs through AASHTO), and collaboration (FHWA) all play key roles in driving implementation. Through both formal and informal processes, these organizations create avenues for putting NCHRP products to work quickly and effectively.

Paths to Practice

Implementation channels at TRB

Implementation starts at TRB with NCHRP itself. In some cases, NCHRP uses state-provided funds to implement research results directly. Examples include training classes and workshops for transportation agencies on topics as diverse as the *Highway Safety Manual* and the *Mechanistic-Empirical Pavement Design Guide*. Other examples are *NCHRP Report 600* training modules for human factors guidelines and the e-learning website for mobile LiDAR developed from *NCHRP Report 748*.

Beyond individual projects, NCHRP has targeted programs that encourage ongoing implementation, such as its Synthesis Program (NCHRP Project 20-05) and U.S. Domestic Scan program (NCHRP Project 20-68A).

The NCHRP senior program officers who oversee research projects keep implementation in mind throughout the life of a research project, from start to completion and beyond. This is evident in the diverse ways that NCHRP promotes implementation and engages in outreach to a wide range of practitioners who can benefit from research results. Examples include the NCHRP-hosted Bridges and Structures website; NCHRP's "Impacts on Practice" publications, which highlight how NCHRP projects are making a difference on the transportation front lines; and TRB's popular webinar program discussing topical NCHRP research results.

> "By sitting down with AASHTO technical committees, NCHRP gains firsthand, up-to-date information on what practitioners need."

The NCHRP-AASHTO partnership

Beyond its own efforts, NCHRP has a highly productive working partnership with AASHTO. In some respects, this is formalized: AASHTO's Standing Committee on Research selects the NCHRP projects to be funded every year, and, in turn, other AASHTO committees depend on the research results to create and update

(continued)

Implementation Strategies *AT A GLANCE*

- **Innovative Outreach:** NCHRP staff members continue to develop innovative dissemination tools to circulate research findings; they welcome comments on what is most effective.
- **Targeted Findings through NCHRP Panels:** Encouraging appropriate AASHTO committee members to serve on NCHRP panels helps assure implementable findings.
- **Building National Networks:** Partnerships among NCHRP, AASHTO, and FHWA illustrate the importance of relationship building at the national level.

NCHRP—Transportation research that works

Objective national highway research since 1962 • Focused on practical problems of state DOTs • Contract researchers competitively selected • Overseen by balanced panels of technical experts • Reviewed by TRB highway specialists

AASHTO standards. A few of the many widely used AASHTO publications that depend on NCHRP results are the *Highway Safety Manual*, the *LRFD Bridge Design Specifications*, and AASHTO's "Green Book" on geometric design of highways and streets.

> "Getting the appropriate AASHTO committee chair to serve on the NCHRP project panel ... helps assure that we'll get usable results."

Less formally, NCHRP technical experts work closely with corresponding AASHTO committees, subcommittees, and technical groups on an ongoing basis to advance NCHRP findings into practice. One example is in the area of bridges and structures, where about 30 NCHRP projects are underway at any time. TRB Senior Program Officer Waseem Dekelbab regularly reports to AASHTO's Subcommittee on Bridges and Structures about research progress, providing interim results and seeking feedback for the principal investigators.

AASHTO brings together state bridge engineers, and NCHRP staff works closely with them to better understand their research needs.

Dekelbab attends as many of the technical committees as he can. "By sitting down with AASHTO technical committees, NCHRP gains firsthand, up-to-date information on what practitioners need," he says. Dekelbab also works to secure AASHTO input at the beginning of the NCHRP research process. "Getting the appropriate AASHTO committee chair to serve on the NCHRP project panel as the chair or member helps assure that we'll get usable results."

In another example of close partnership, TRB Senior Program Officer Ray Derr created TRB web pages to capture completed and in-progress NCHRP research that relates to the AASHTO committees on Traffic Engineering (trb.org/nchrp/Pages/719.aspx) and Geometric Design (trb.org/nchrp/Pages/721.aspx).

Implementation from a federal perspective

Where AASHTO represents the state transportation agencies, FHWA represents the U.S. DOT's interest in seeing NCHRP results used. Monique Evans, director of FHWA Safety Research and Development, explains the unique working relationship between NCHRP and FHWA: "As a co-sponsor of NCHRP," she says, "FHWA can submit problem statements, may contribute additional funding, and has a liaison on most—if not all—NCHRP project panels."

FHWA implementation of NCHRP research is typically planned in advance, especially for projects where FHWA either submitted a proposal or contributed funding. "In these cases," Evans says, "an NCHRP research topic may be part of an FHWA research roadmap or strategic plan."

NCHRP projects serve as foundational resources for many FHWA projects and programs, such as Every Day Counts and Highways for LIFE. In some cases, FHWA has applied NCHRP results directly. A notable example is *NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features*, which was official federal policy for years. In another case, FHWA's *Manual on Uniform Traffic Control Devices* was directly informed by NCHRP projects that were conducted specifically to update the manual.

FHWA also commonly offers guidance and encouragement to transportation agencies to use particular approaches based on NCHRP and other research programs, often through its resource centers and division offices.

> "An NCHRP research topic may be part of an FHWA research roadmap or strategic plan."

FHWA's Every Day Counts initiative helps accelerate the use of time- and cost-saving innovations, many based on NCHRP research products.

A Long View on Improving Implementation

Finding new and more effective opportunities for implementing NCHRP research is an ongoing and highly collaborative process. It is also NCHRP's longstanding commitment. This *Paths to Practice* publication is part of a larger NCHRP project completed in 2014 to identify implementation best practices for NCHRP products and to uncover challenges—and solutions—to wider implementation.

> "AASHTO ... will examine [this] report and consider the recommendations for improving and expanding implementation of NCHRP products."

Hedges notes that the NCHRP report, *Evaluating Implementation of NCHRP Products: Building on Successful Practices*, will serve as guidance for practitioners, managers, and executives alike. "In addition," he says, "AASHTO's Standing Committee on Research will examine the report and consider the recommendations for improving and expanding implementation of NCHRP products in the future."

This project is the latest in the NCHRP research series 20-44, "Accelerating the Application of NCHRP Research Results," which has been seeking and developing improved implementation channels for years. For more information about the 20-44 series, see apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=588.

ACKNOWLEDGEMENT OF SPONSORSHIP Work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies.
DISCLAIMER The opinions and conclusions expressed or implied in reports are those of the research agencies. They are not necessarily those of the Transportation Research Board, the National Research Council, or the program sponsors.

States Spur Effective Use of NCHRP Products

State DOT research offices have a unique relationship with NCHRP. Together with senior management, state research staff members help develop NCHRP's research projects. They also lead efforts to implement NCHRP results and track and quantify the benefits. States' NCHRP implementation strategies and successes are as diverse as the states themselves.

Part of a Larger Picture

NCHRP is one element of each state's efforts to meet its transportation research needs. NCHRP complements the federally funded State Planning and Research Program, which is tailored to meet individual state needs, and the Transportation Pooled Fund Program, targeted at groups of states with shared interests.

As the states' collaborative research program, NCHRP addresses key topics of common and pressing concern. It is the go-to place for conducting core research to develop or update national standards and to address the emerging issues affecting the transportation system from coast to coast.

However, while the program is national in scope, implementation of NCHRP products is largely a state activity. Reflecting their unique needs and perspectives, states have developed their own approaches for interfacing with NCHRP: how they implement NCHRP findings as part of their larger state research programs, and how they evaluate and demonstrate the difference NCHRP is making. The examples here—by no means exhaustive—illustrate some of the ways that states ensure maximum benefit from participating in the program.

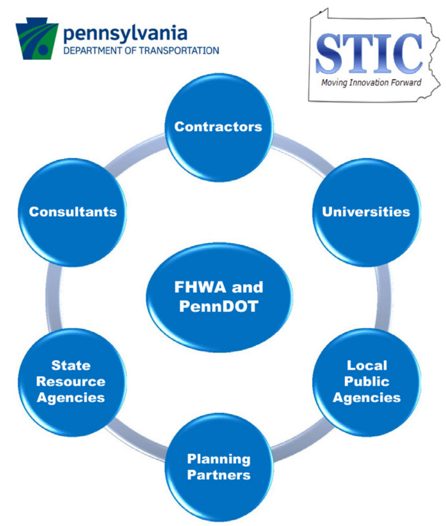
> "NCHRP is highly leveraged, and it makes sense to look there first."

Paths to Practice

Building NCHRP into the program

Transportation agencies that make the most of NCHRP products know that implementation doesn't happen by accident. Instead, they establish processes to regularly consider NCHRP as a path to solving their transportation challenges.

For example, in Georgia, the state DOT instituted Research Technical Advisory Groups



Pennsylvania DOT's State Transportation Innovation Council regularly considers NCHRP products as potential solutions to the state's transportation challenges.

to consider research needs and funding options. The groups looks at NCHRP first among possible channels to solve Georgia DOT's research needs. "NCHRP is highly leveraged, and it makes sense to look there first," says David Jared, chief of Georgia DOT's Research and Development Branch. Jared notes that this must be for issues of shared national concern, not Georgia-specific problems.

States also have processes to look at completed NCHRP projects. Pennsylvania's State Transportation Innovation Council formally brings together all state stakeholder groups—PennDOT, FHWA, contractors, universities, local public agencies, planning partners, state resource agencies, and consultants—to consider the full landscape of research solutions.

"As Pennsylvania's State Transportation Innovation Council considers possible new technologies and practices for our state, we see NCHRP as a good source of nationally vetted research," says Michael Bonini, manager of PennDOT's Research Division. "The research need has gone through an exhaustive process through AASHTO's Standing Committee on Research. We anticipate a lot of benefits for the department."

> "We see NCHRP as a good source of nationally vetted research."

PennDOT's use of NCHRP safety research is one standout example of sustained implementation at the institutional level. Bonini notes that the agency relies on NCHRP results to dictate which safety countermeasures should be applied in the districts. He says that the agency is implementing about 90 percent of NCHRP safety recommendations in one way or another.

(continued)

Implementation Strategies *AT A GLANCE*

- **The First Stop for Answers:** Standard practice for Georgia's Research Technical Advisory Groups is to check NCHRP products first for research solutions.
- **Putting NCHRP into Stakeholders' Hands:** Pennsylvania regularly considers NCHRP products as innovations that can have an impact.
- **Measuring the Value of NCHRP:** Utah's value assessment of high-priority NCHRP projects keeps UDOT engaged in the program.
- **Addressing Practical Needs:** Agencies with strong implementation cultures are likely to recognize and act on opportunities to use NCHRP products.

NCHRP—Transportation research that works

Objective national highway research since 1962 • Focused on practical problems of state DOTs • Contract researchers competitively selected • Overseen by balanced panels of technical experts • Reviewed by TRB highway specialists

Agencies work to implement NCHRP products on a daily basis. States like Iowa, Minnesota and Pennsylvania have research staff dedicated to implementation. These experts consider research products from all sources, including NCHRP, with an eye for solutions that may be relevant and valuable in their own state.

The value proposition

Quantifying the value of research—not just NCHRP research, but transportation research in general—is a stated goal (and a challenge) for many state programs. Cameron Kergaye, director of research for Utah DOT, explained the process in his state for enumerating the benefits of NCHRP research. It's an extended process that starts with project balloting when the NCHRP problem statements are up for vote among all the states.

> "We can see how many millions of dollars of high-priority research is being funded .... It's a huge value."

"UDOT involves subject experts in the annual voting process, asking them to provide numerical ratings for each proposed NCHRP project," Kergaye says. This helps Utah prioritize which NCHRP projects are likely to provide the most value for the state. Beyond that, when AASHTO later approves the final slate of annual NCHRP projects, Utah turns back to its rankings to compare its high-priority projects to the funded program.

> "Following up with DOT staff to find out if and how they have used NCHRP results would be informative."

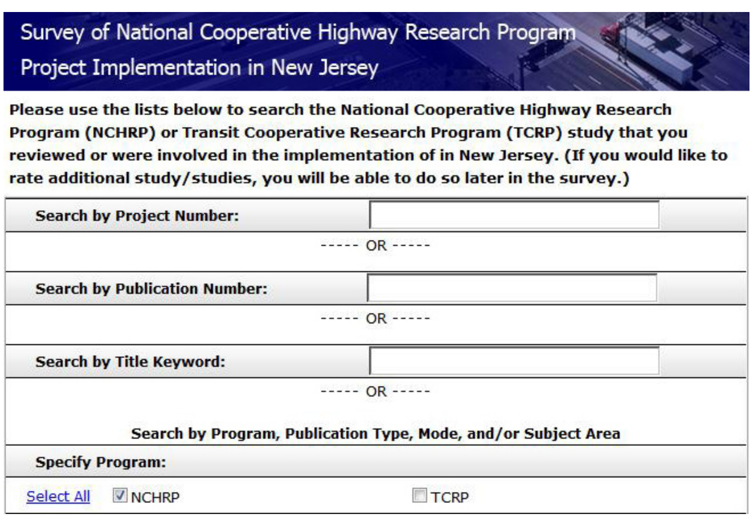
This process allows UDOT to quantify how well it is leveraging its investment in NCHRP. "We can see how many millions of dollars of high-priority research is being funded given our state's contribution to NCHRP," Kergaye says. "It's a huge value, and we share that information around our state. UDOT gets a lot of mileage out of this assessment."

Documenting the benefits

The dollars, though, just tell part of the story. Georgia's David Jared shared the thoughts of a retired colleague from another state: "He would often remark, 'I'm investing $1 million per year in NCHRP and I'm getting $30 million of research.' Yet it wasn't clear if he knew what that $30 million meant in terms of value to his state. State research directors like myself want to be able to say with confidence, 'Here are the documented benefits.'"

Camille Crichton-Sumners, manager of New Jersey DOT's Bureau of Research, attempted to answer that very question. Her office undertook a study to determine the extent of NCHRP research implementation in the state. NJDOT's technical memorandum *Review of NCHRP Study Implementation at the NJDOT* describes the results of a survey of research consumers in the state that sought to learn how national cooperative research programs (NCHRP and others) met New Jersey's practical needs.

Though the survey response pool was too small to draw firm conclusions, the study findings were encouraging: 67 percent of such projects were partially implemented, and 22 percent were fully implemented.



Survey of National Cooperative Highway Research Program
Project Implementation in New Jersey

Please use the lists below to search the National Cooperative Highway Research Program (NCHRP) or Transit Cooperative Research Program (TCRP) study that you reviewed or were involved in the implementation of in New Jersey. (If you would like to rate additional study/studies, you will be able to do so later in the survey.)

Search by Project Number:

----- OR -----

Search by Publication Number:

----- OR -----

Search by Title Keyword:

----- OR -----

Search by Program, Publication Type, Mode, and/or Subject Area

Specify Program:

Select All ☑ NCHRP ☐ TCRP

A survey of research consumers helped New Jersey DOT determine the extent of NCHRP use and value.

"This kind of information is not easy to capture," Crichton-Sumners says. "People commonly don't remember how they might have used NCHRP research." Her office, like many other state research departments, passes along final NCHRP reports to subject matter experts in the agency. "Following up with DOT staff to find out if and how they have used NCHRP results would be informative and worthwhile," Crichton-Sumners says, noting it would be difficult in practice.

At Utah DOT's annual research workshop, staff sets the state's priorities for NCHRP.

The Implementation Culture

Even as states strive to show how—and how much—they use NCHRP, there remains a strong and pervasive sense among research staff that NCHRP research is extremely valuable. States continue to perfect the formula for putting NCHRP products to work.

States that successfully use NCHRP research share one thing in common: They have all made it a part of their culture. They encourage submission of NCHRP problem statements and staff participation on panels. Stakeholder and technical groups regularly consider NCHRP findings for local use. State DOT research staff passes along NCHRP findings to the right practitioners who know the needs on the ground—and who will recognize a solution.

> "NCHRP panelists ultimately become champions for innovation, and they help market the results to the districts."

Ideally, project panelists become advocates for the research findings as well. That has been a formula for success in Pennsylvania. "NCHRP panelists ultimately become champions for innovation, and they help market the results to the districts," Bonini says.

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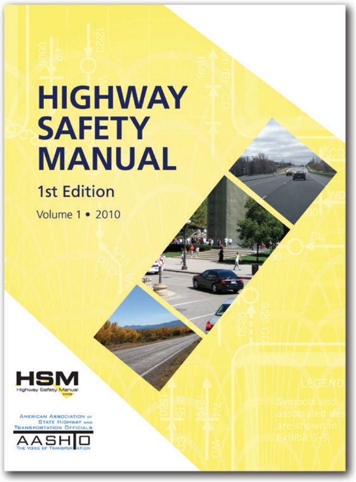
A Revolution in Highway Safety Planning

The first edition of the *Highway Safety Manual* is the product of more than $3 million of NCHRP research over 10 years. Using quantitative methods, the manual gives practitioners state-of-the-art tools to predict and evaluate the safety-related impacts of transportation decisions throughout the project development process.



The first edition of the *Highway Safety Manual* is a milestone in science-based safety planning.

Making Safety a Science

The safety of the traveling public on the nation's roadways is a top priority among transportation agencies, both at the national and the state levels. Yet even as recently as 1999, planners, designers, and traffic engineers had no consistent and reliable way to predict the safety impacts of decisions made throughout the project development process. Without a standard, data-driven approach available for anticipating potential crashes, safety considerations often took a back seat to other planning and development considerations.

In 1999, a TRB joint task force was established to initiate the development of an authoritative guide for evaluating the safety performance of transportation projects. With strong support from AASHTO and FHWA, TRB spearheaded a 10-year research and development process that led to publication of the nation's first *Highway Safety Manual* (HSM) in 2010.

The HSM fundamentally changes the way transportation professionals develop projects by supporting a quantitative safety evaluation of specific treatments or programs and predictive modeling of the safety impacts from varying geometric or operational decisions. The HSM consists of four parts, all intended to support front-line decision making in transportation agencies:

- Part 1: Introduction, Human Factors, and Fundamentals of Safety
- Part 2: Roadway Safety Management Process
- Part 3: Predictive Methods
- Part 4: Crash Modification Factors

NCHRP Projects 17-18(4), 17-26, 17-27, 17-29, 17-34, and 17-36 provided the foundational research and production coordination for this edition. Additional studies fed into the ultimate manual and are contributing to ongoing enhancements.

Paths to Practice

Building the foundation

It was clear from the start that developing the new manual would require extensive and sustained coordination among multiple organizations, not only to effectively conduct the research needed to develop the HSM content but also to provide the organizational channels needed to produce, distribute, and promote the results. The new TRB joint task force spearheaded development of the HSM and provided the necessary framework for ongoing collaboration among TRB, AASHTO, and FHWA.

"It was a formal and committed process," says Geni Bahar, the investigator with NAVIGATS Inc. for HSM Parts 1 and 2. "Going from a report to a manual involved many years of work with volunteers from TRB and practitioners around the country." Each step in the development process required extensive review and approval from the NCHRP project panels guiding the research, the TRB task force coordinating the overall effort, and the AASHTO committee that would ultimately publish the manual. "We had to get the trust as well as the confidence of the professionals and researchers together to encourage adoption of the HSM," Bahar says.

> "It was a formal and committed process."

> "We presented the science as it evolved to the TRB committees to make sure they were aware of what we were doing as we were doing it."

Raising awareness, anticipating challenges

Getting support for the HSM at the national level was only the beginning, however. The TRB task force members knew that getting buy-in for the HSM among end users would

(continued)

Implementation Strategies
AT A GLANCE

- **Cooperative National Effort:** Developing and implementing the *Highway Safety Manual* required broad and sustained collaboration among TRB, AASHTO, FHWA, and other transportation stakeholders.
- **Engaging End Users:** TRB established a user liaison subcommittee that was dedicated to educating end users about HSM, inviting feedback, and addressing practitioner concerns.
- **Providing Implementation Tools:** TRB, AASHTO, and FHWA worked together to support practitioner implementation by producing companion tools and resources and funding pilot implementations.

be critical for widespread implementation. The task force established a user liaison subcommittee to identify potential HSM users and effective approaches to promoting the new concepts in the manual.

Chaired by Bahar, the subcommittee began simply by spreading the word about HSM at TRB conferences and inviting technical feedback from TRB committees. The group's work quickly became more formal, with systematic outreach efforts planned during frequent meetings and teleconferences. "We presented the science as it evolved to the TRB committees to make sure they were aware of what we were doing as we were doing it," Bahar says. "We also invited state DOT engineering practitioners, through AASHTO, into the process throughout the HSM development. We worked with both sides—the TRB researchers as well as the practitioners who would be adopting and using the manual—so that when the manual was ready, there would be confidence and understanding."

> "We needed to create enough know-how to overcome the fears of change."

HSM Implementation Tools and Support

- HSM web portal: www.highwaysafetymanual.org
- *HSM Implementation Guide for Managers* (including who to involve, how to address questions, what additional data may be needed, how to develop an implementation plan, and lessons from lead states)
- *Integrating the HSM into the Highway Project Development Process* (including planning, design, operations, and maintenance)
- Protocols and guidance documents for using crash modification factors and other resources with the HSM
- Lead state pilot implementation projects funded through NCHRP
- Companion tools and AASHTOWare, such as FHWA's Safety Analyst, Crash Modification Factors Clearinghouse, and Interactive Highway Safety Design Model
- Brochures, training materials, and technical support
- Workshops and webinars
- HSM User Discussion Forum

The subcommittee members also worked hard to acknowledge and address the concerns and challenges standing in the way of implementation in the states. For example, the data-driven approaches to safety quantification in the HSM represented a huge shift in practice for most transportation agencies. "The practice was far away from what we were trying to bring forward," Bahar says. "We needed to create enough know-how to overcome the fears of change."

Some states also expressed concerns about potential liability in relying on the manual to estimate safety impacts. The task force involved planners and legal experts to address potential issues throughout the development process.

Providing tools and technical support

Since the *Highway Safety Manual* became ready for purchase and use by practitioners in 2010, TRB, AASHTO, and FHWA have made every effort to provide support and guidance for putting the HSM into practice. A comprehensive HSM online portal (www.highwaysafetymanual.org) developed by AASHTO provides a single place to access numerous HSM guidance and reference documents, case studies, protocols, brochures, and training materials. An HSM User Discussion Forum also promotes information sharing and problem-solving among practitioners.

Leanna Depue, highway safety director at the Missouri DOT, says that implementation on this scale is always a work in progress. "You can't just produce a manual," she says. "You have to develop implementation strategies and nurture implementation. It's going to require updating for many years to come."

Implementation Success

The HSM has already been implemented in some form by more than half of the states, expedited through the participation of 21 DOTs as lead states or support states in the Lead States Initiative for Implementing the *Highway Safety Manual* (NCHRP 17-50). FHWA has also published case studies on HSM implementation in five states (Florida, Illinois, Idaho, New Hampshire, and Ohio), highlighting how transportation agencies are moving forward with enhancing their data collection efforts, developing new policies, assessing their skill gaps, and developing implementation plans to support HSM use.

The HSM methodology allows for the systematic comparison of design alternatives and their anticipated impacts on safety.

The TRB Highway Safety Performance Committee (ANB25) has taken the place of the joint task force to continue implementation coordination of the HSM with AASHTO and FHWA. These efforts include new research projects that will help enhance and expand agency capabilities when using the manual. Even as the methodology advances and evolves, the first edition of the HSM will remain a true milestone in science-based safety planning—the core of a fundamental shift in how transportation agencies plan for safety throughout the project development process.

> "You have to develop implementation strategies and nurture implementation. It's going to require updating for many years to come."

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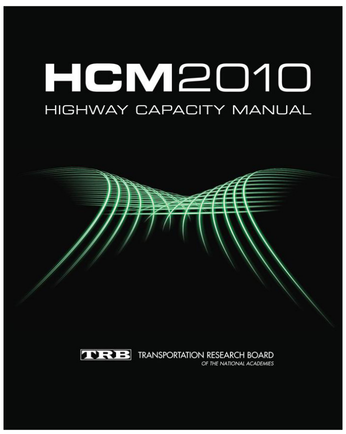
Updating the Authoritative Guide on Capacity

The *Highway Capacity Manual* is the go-to source for information about evaluating the capacity of transportation facilities. The latest edition provides practitioners with the most up-to-date analytical tools by incorporating more than $5 million in NCHRP research and drawing on a broad collaborative effort by the transportation community.

Responding to Evolving Practices

For more than 60 years, the Transportation Research Board's *Highway Capacity Manual* (HCM) has provided engineers with state-of-the-art techniques for analyzing the capacity and level of service for transportation facilities, including roadways, intersections, and roundabouts. The HCM is the definitive guide for transportation engineers worldwide who wish to determine how much traffic a transportation facility can safely accommodate at a prescribed level of service, defined by such performance measures as average traffic speed and travel time.



Used worldwide, the *Highway Capacity Manual* is the definitive guide for determining the capacity and level of service for transportation facilities.

However, as methods for evaluating capacity and level of service evolve, updates to the HCM are needed to provide transportation practitioners with the best available analytical tools. Since its first publication in 1950, the HCM has seen five editions, the most recent issued in 2010 (www.trb.org/Main/Blurbs/164718.aspx). TRB's 2010 update to the HCM:

- For the first time, provides users with a method for an integrated multimodal analysis of urban streets.
- Addresses active traffic management such as managed lanes and smart lanes.
- Gives planners the tools to quickly determine the size of future facilities.
- Includes an electronic volume with comprehensive case studies.

Paths to Practice

Incorporating a broad range of NCHRP research findings

The 2010 HCM was a major undertaking, incorporating more than $5 million in research from 10 NCHRP projects and two FHWA projects.

One of these projects, NCHRP Project 03-82, improved default values for analyzing capacity and level of service. Engineers use default input values—pedestrian and vehicle flow rates, or road and signal geometries—when there is insufficient local field data for an analysis. The defaults in the previous edition of the HCM did not fully reflect the variety of traffic conditions across the United States and sometimes yielded analyses of limited usefulness.

"NCHRP 03-82 helped improve the accuracy of the most significant default values for the HCM by revising them based on field data from around the United States," says John Zegeer, principal investigator for NCHRP 03-82, and senior principal engineer at Kittelson & Associates. "This makes analyses of capacity and level of service much more reliable."

> "NCHRP 03-82 helped improve the accuracy of the most significant default values for the HCM."

Another project, NCHRP 03-64, developed a companion guide to the HCM to show how to apply its methodologies to real-world problems. "Prior to the 2000 edition, the HCM only provided simple example problems to illustrate methodologies," says Tom Creasey, transportation planning manager with Stantec. Creasey chaired the NCHRP 03-64 panel and is secretary of the TRB Highway Capacity and Quality of Service (HCQS) Committee, which oversees the HCM. "The companion guide educates users on how to use the HCM for complex problems that require more than plugging numbers into formulas," Creasey says.

> "The HCM's new multimodal analysis tools look at the urban environment from the point of view not just of traffic engineers but of travelers."

Creasey was also a member of the panel for NCHRP 03-70, which incorporated

(continued)

Implementation Strategies *AT A GLANCE*

- **Cooperative National Effort:** Updating the Highway Capacity Manual involved broad collaboration among TRB, AASHTO, FHWA, and other transportation stakeholders.
- **An Ongoing Research Commitment:** Refining and building on previous work facilitated the implementation of past successful research.
- **Keeping Users in Mind:** Transportation practitioners were consulted at multiple stages of the revision process to make sure the new HCM would meet their needs.
- **Dissemination through Partners:** TRB's capacity committee and the Institute of Transportation Engineers used webinars and other channels to share updates and facilitate use of the new HCM.

methods for the multimodal analysis of urban streets. “The HCM’s new multimodal analysis tools look at the urban environment from the point of view not just of traffic engineers but of travelers,” he says. “The mathematical models were created based on how drivers, pedestrians, bicyclists, and transit users rated their experience of trips.” The update will make the HCM far more useful to planners, helping them to evaluate the trade-offs involved in how various modes share an urban street.

> “The manual is larger than any one committee.”

A collaborative effort by the transportation community

The HCM is a definitive guide that embodies decades of research. Updating it was an enormous effort that involved the cooperation of TRB, AASHTO, and FHWA over a number of years. “The manual is larger than any one committee,” says Ray Derr,

NCHRP and FHWA Research for the 2010 HCM Update

- NCHRP Project 03-60, Capacity and Quality of Service of Interchange Ramp Terminals
- NCHRP Project 03-60A, Validation and Enhancement of the *Highway Capacity Manual*’s Interchange Ramp Terminal Methodology
- NCHRP Project 03-64, *Highway Capacity Manual* Applications Guide
- NCHRP Project 03-65, Applying Roundabouts in the United States
- NCHRP Project 03-70, Multimodal Level of Service Analysis for Urban Streets
- NCHRP Project 03-75, Analysis of Freeway Weaving Sections
- NCHRP Project 03-79, Measuring and Predicting the Performance of Automobile Traffic on Urban Streets
- NCHRP Project 03-82, Default Values for Capacity and Quality of Service Analyses
- NCHRP Project 03-85, Guidance for the Use of Alternative Traffic Analysis Tools in Highway Capacity Analyses
- NCHRP Project 03-92, Production of the Year 2010 *Highway Capacity Manual*
- Two FHWA projects: Evaluation of Safety, Design, and Operation of Shared-Use Paths; and Active Traffic Management Measures for Increasing Capacity and Improving Performance

TRB senior program officer on NCHRP 03-92, the umbrella project for updating the manual. “Updating it required extensive involvement from the transportation community as a whole.”

Part of that effort involved consulting transportation professionals to make sure the 2010 update would meet their needs. As part of project 03-92, researchers conducted focus groups with HCM users in Florida, Maryland, and Oregon. “These focus groups provided critical insights into the content and organization of the manual,” Derr says.

As it was completed, the HCM was also vetted in a yearlong review process by more than 300 TRB professionals and TRB HCQS Committee members. “The HCQS Committee reviewed results of each project and made an independent determination as to whether they were valid and should be included,” Zegeer says. “Their oversight was critical.” The HCQS also obtained feedback through joint summer meetings with the Institute of Transportation Engineers (ITE) as well as focus groups sponsored by the ITE.

The HCM has a wide reach

Derr, Creasey, and Zegeer agree that the impact of the HCM on transportation infrastructure in the United States cannot be emphasized enough. Its methods are used to determine everything from the number of lanes on streets to the timing of traffic signals. It is also highly influential on the content of capacity manuals worldwide.

“This manual has a huge amount of weight, setting the commonly accepted standards for level of service,” Derr says. “It’s widely used by both local agencies and state DOTs to determine how to keep traffic moving. It is also frequently cited in local regulations.”

To ensure the HCM’s continued relevance, the HCQS was very active in sharing the results of the 2010 update. That included numerous webinars, several of which were

> “Focus groups provided critical insights into the content and organization of the manual.”

Among many other updates, the 2010 *Highway Capacity Manual* gives users tools to incorporate bicycle and pedestrian planning into their traffic engineering decisions.

co-hosted by ITE, as well as ITE meetings, according to Derr. “The HCQS is a very busy committee,” he says. “Dissemination is a big part of their job.”

> “This manual has a huge amount of weight.... It’s widely used by both local agencies and state DOTs to determine how to keep traffic moving.”

Another major route for the impact of the HCM is companion software developed and maintained by the University of Florida’s McTrans Center. “The Highway Capacity Software is frequently updated and faithfully implements HCM procedures,” Derr says, “giving transportation professionals an important tool for applying HCM methodologies.”

Implementation Success

Because of its wide use and impact on transportation professionals worldwide, the HCM is a standout example of a successful implementation of NCHRP research. “It would be hard to think of a better implemented project than the HCM,” Creasey says. “Not only does it meet a demonstrated need, but it has met the challenge of accommodating more and more needs in response to feedback from the user community.”

The result is a manual that is increasingly useful to engineers with each update. “This latest edition significantly changes how engineers evaluate the possible effects of highway projects,” says Zegeer. “It gives them better tools than ever for evaluating capacity and quality of service.”

ACKNOWLEDGEMENT OF SPONSORSHIP Work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies.

TRB TRANSPORTATION RESEARCH BOARD
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NCHRP Reports 568 and 593

Standards and Training for Scour Prevention

Transportation agencies have long needed comprehensive guidance on riprap and other bridge scour countermeasures. Two NCHRP projects established this guidance and resolved a design dilemma concerning riprap that has long interested engineers. The projects' principal investigators played a critical role in implementing the results, helping to author FHWA Hydraulic Engineering Circulars and communicate results to state DOTs.

Bridge Scour Countermeasures: A Need for Practical Guidance

The most common cause of highway bridge failures in the United States is bridge scour, a type of erosion in which moving water displaces sediments such as sand and rocks from around bridge piers and abutments. The gaps left by scour can weaken the support for bridges and lead to their collapse.

NCHRP Projects 24-07(2) and 24-23 developed comprehensive guidance for countermeasures to bridge scour, a leading cause of highway bridge failures.

To prevent bridge scour, engineers use a variety of countermeasures, including piers in waterways to control flow, and riprap placed around piers and abutments to protect them from erosion. Because countermeasures are both necessary to bridge integrity and costly, their selection, design, and construction are important issues for transportation agencies. There has long been a need for practical guidance on the use of scour countermeasures for pier protection.

> "Implementation is more successful when there's a product in demand."

To address this need, NCHRP managed several research projects investigating the prediction, evaluation, monitoring, and prevention of bridge scour. In particular, the need for comprehensive design guidance on bridge scour countermeasures led to NCHRP Project 24-07(2) and the resulting product, *NCHRP Report 593: Countermeasures to Protect Bridge Piers from Scour* (www.trb.org/Main/Public/Blurbs/156796.aspx).

A related effort, NCHRP Project 24-23, addressed the design of riprap countermeasures in particular. At the time the project was initiated, existing techniques and procedures for design of riprap protection were confusing and difficult to apply, and there were inconsistencies in the literature as to the best methods for determining the size and extent of riprap installation, which can vary widely depending on the circumstances. Consequently, most states had differing specifications for classifying riprap size and gradation, and construction practices varied widely in effectiveness.

AASHTO and FHWA initiated research to develop standard specifications and construction practices to ensure proper placement and performance of riprap countermeasures, resulting in *NCHRP Report 568: Riprap Design Criteria, Recommended Specifications, and Quality Control* (www.trb.org/Main/Public/Blurbs/155703.aspx).

Paths to Practice

Communicating results with FHWA

Getting the research results into the hands of practitioners was the first step to implementing the findings. FHWA's Hydraulic Engineering Circulars (HECs) provided the ideal avenue for accomplishing this step.

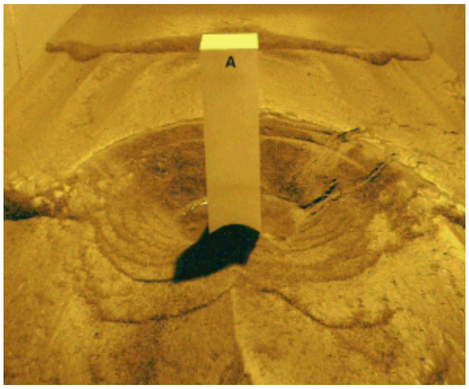
> "Implementation really comes down to states trying out these countermeasures. As they do so, they may find that some things work better than others."

"For years, the FHWA Hydraulic Engineering Circulars have been the bible for designing and evaluating scour countermeasures," says NCHRP 24-23 panel member Stan Davis, consultant to the Maryland State Highway Administration (SHA). "They've really been a very good resource for putting out information."

(continued)

Implementation Strategies *AT A GLANCE*

- **Leveraging FHWA Channels to Communicate Results:** Results were incorporated into widely used FHWA Hydraulic Engineering Circulars.
- **Tailoring Research to Practitioner Needs:** Because scour is a leading cause of bridge failure, the results were quickly used to meet an urgent need.
- **Continued Research Team Involvement:** PIs helped write circulars and conducted conference presentations and National Highway Institute training.
- **Improving Established Methods and Specifications:** Panel members from Maryland, California, and Colorado led efforts to apply the scour countermeasures to their states' practices and guidelines.



Lab tests on scale model bridge piers indicated that riprap performed best when it extended a distance of twice the pier width in all directions.

The results of *NCHRP Reports 593* and *568* directly fed into updating HECs, which have a wide reach with engineers nationwide. "This made coordination with FHWA a natural part of project implementation," says NCHRP 24-07(2) panel member Catherine Crossett Avila, an engineer formerly with the California Department of Transportation.

The results of NCHRP 24-07(2) have been incorporated into Hydraulic Engineering Circular 23 (HEC 23), *Bridge Scour and Stream Instability Countermeasures*. The results of NCHRP 24-23 have also been incorporated into that circular as well as HEC 18, *Evaluating Scour at Bridges*, which Davis co-authored.

A high-quality product that's in demand

Reaching practitioners with the information, however, is just part of the implementation equation. "Implementation is more successful when there's a product in demand," Davis says. "Scour countermeasures are of continuing interest for state DOTs."

Not only are the HECs widely used by engineers, but their update modifies a key equation critical to riprap design. In implementing results, researchers took rock slope protection specifications and made them more robust, modifying the equation so that practitioners have better guidance on how to use riprap as a pier scour countermeasure.

Further, the NCHRP research resolved a problem of great interest to engineers.

> "For years, the FHWA Hydraulic Engineering Circulars have been the bible for designing and evaluating scour countermeasures."

"There had been a question as to which methods for designing riprap countermeasures were most appropriate for bridges," Davis says. "Everyone recognized that this was something we needed to know, and *NCHRP Report 568* resolved this issue in favor of FHWA's method after examining a number of other methods." The study also provided helpful information about using the U.S. Army Corps of Engineers' riprap design method for application at other locations.

Proactive principal investigators make a critical difference

Also critical to the successful implementation of *NCHRP Reports 593* and *568* was the direct involvement of principal investigator Pete Lagasse, who helped to write HEC 18 and HEC 23. He and co-investigators were very active in disseminating project results.

> "It's critical to successful implementation to pick principal investigators who will stick with a project and go the extra mile."

"Not only did the PIs for NCHRP 24-07(2) essentially implement the project results by authoring HEC 23," Avila says, "but they also gave several conference presentations."

They reached out to state DOTs as well. According to Arun Shirole, NCHRP 24-07(2) chair and former New York State DOT deputy chief engineer, the principal investigator conducted training courses in about a dozen states, via FHWA's National Highway Institute. "Introducing the results of these projects to state DOTs is important for implementation to succeed," Shirole says.

Selecting the right principal investigator is key to implementation. "You want a PI who's well connected to the community, who you want to implement the results, and who is proactive about communicating these results," Avila says. "In general, it's critical to successful implementation to pick principal investigators who will stick with a project and go the extra mile."

> "NCHRP 24-23 is one of the most successful NCHRP projects I've been involved with because it resolved a specific dilemma about the preferred design method for riprap countermeasures for bridges."

An Implementation Success

Ultimately, implementation is a matter of how state and local agencies use results. "Implementation really comes down to states trying out these countermeasures," Avila says. "As they do so, they may find that some things work better than others."

Avila herself has been involved in implementing the new riprap methods on a bridge in Chico, Calif., and knows of its use on a Colorado bridge. Maryland SHA is also actively using research results. "The Office of Structures incorporated this information into Maryland's highway design manual," Davis says, "and Maryland SHA has already adopted these methods."

Overall, the interviewed panel members see NCHRP Projects 24-07(2) and 24-23 as exceptional examples of successful implementation.

"NCHRP 24-07(2) is one of NCHRP's great success stories, and the most successful NCHRP project I've worked on," Avila says.

Davis feels similarly about NCHRP 24-23. "NCHRP 24-23 is one of the most successful NCHRP projects I've been involved with," Davis says, "because it resolved a specific dilemma about the preferred design method for riprap countermeasures for bridges."

If properly designed, inspected, and maintained on a regular basis, riprap placed around bridge piers can provide long-term protection against scour. (Image courtesy Virginia DOT)

ACKNOWLEDGEMENT OF SPONSORSHIP Work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies.

Optimizing AASHTO's Bridge Software

Managing bridge inventories is a complex process that most DOTs undertake using AASHTOWare Bridge Management software. NCHRP research was critical to updating this software with new capabilities. The improved tool helps managers better prioritize funds and minimize risk when making decisions about bridge preservation, rehabilitation, and replacement.

Most U.S. transportation agencies use AASHTOWare Bridge Management software to manage their large bridge inventories.

Including Multiple Criteria for Bridge Management

To manage their inventory of bridges, transportation agencies must determine when and how to maintain bridges to keep them safe and performing well even as they age. Bridge managers must establish performance measures and the most cost-effective use of limited funds to meet those measures.

The AASHTOWare Bridge Management software, formerly called Pontis, allows users to track and store bridge maintenance data; model the expected deterioration of bridges; and ultimately make more cost-effective decisions for bridge preservation, rehabilitation, and replacement. The tool also helps agencies comply with the highly detailed inspection regimen required by FHWA.

> "Bridge management must consider performance measures beyond life-cycle costs."

Traditionally, this and similar software tools allowed users to make decisions based only on the objective of minimizing long-term costs as bridges deteriorate. However, other objectives are important to bridge agencies, including safety; traffic flow disruption; and vulnerability to scour, fatigue, and other hazards. Accounting for trade-offs between these various performance criteria allows more balanced bridge management decisions.

"The state of the practice in bridge management was based on bridge deterioration," says Michael Johnson, chief of Caltrans Office of Specialty Investigations and Bridge Management, "yet 40 percent of the money I spend is on vulnerabilities. We needed a way to integrate condition-based objectives with vulnerability criteria."

Todd Thompson, bridge management engineer for South Dakota DOT, commented further on the need. "Bridge management must consider performance measures beyond life-cycle costs," Thompson says. "It must optimize multiple objectives to minimize risk."

The AASHTOWare Bridge Management Task Force proposed a project to update the existing Pontis software. The resulting NCHRP Project 12-67 produced *NCHRP Report 590: Multi-Objective Optimization for Bridge Management Systems* (trb.org/Main/Public/Blurbs/159292.aspx).

Paths to Practice

Collaborating to update AASHTOWare

A key outcome of the NCHRP research was the development of bridge management software modules that allow users to specify multiple performance criteria. This software tool also affords visualization of the life cycles of individual bridges and bridge inventories.

> "It was very easy for the AASHTOWare task force to take over where the NCHRP research panel left off."

According to both Johnson and Thompson, AASHTO is well on its way to implementing this research by updating AASHTOWare Bridge Management software to incorporate multi-objective optimization. "AASHTO has developed an extensive design and has conducted several mini-studies in preparation for software development," says Thompson, who was a panel member for NCHRP 12-67 and will assist in beta testing of the software.

The role of panel members in implementation via their involvement in AASHTO was critical to implementation, according to Johnson, who was not only a panel member

(continued)

Implementation Strategies *AT A GLANCE*

- **Collaboration with AASHTO:** Close ties between research champions and the appropriate AASHTO committee ensured a highly useful research product.
- **Communicating Results, Influencing Legislative Change:** Dissemination of results played a role in the signing of MAP-21 legislation, which requires risk-based asset management by states.
- **Addressing a Critical Need:** The project was steered from the beginning to address a need that was important to practitioners.

"Our dissemination of results for this project played a role in the signing of federal legislation."

and writer of the project proposal, but is the current vice chair of the AASHTOWare Bridge Management committee. "While NCHRP 12-67 was being conducted, this position was held by the project panel's chair," Johnson says. Other NCHRP 12-67 panel members were similarly involved in AASHTO.

These overlapping memberships supported implementation, according to Johnson. "It was very easy for the AASHTOWare task force to take over where the NCHRP research panel left off," he says.

Thompson says the new software will be available in 2015.

Communicating results, influencing legislative change

Beyond their critical overlapping roles in AASHTO, panel members also made presentations at various bridge management conferences and annual meetings.

"The whole project panel has been important," Johnson says."They have been positive advocates for a multi-objective approach." Johnson himself made a presentation to FHWA, and others have gone before AASHTO and TRB committees and facilitated webinars.

This proactive approach to communicating results has had broad consequences. "Our dissemination of results for this project played a role in the signing of federal legislation," Johnson says. Signed into law in 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) requires risk-based asset management by states.

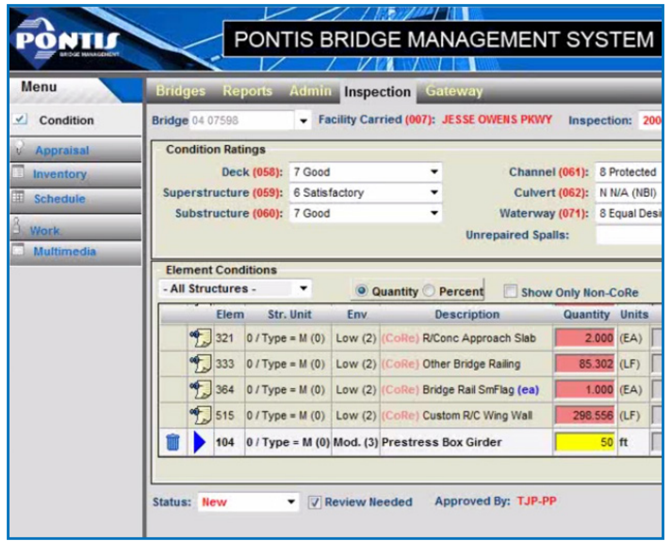
"MAP-21 has very broad implications," Johnson says. "It will change the way bridges are inspected."

A proactive project panel addresses a critical need

The panel for this project was active not just in communicating results and facilitating the update of AASHTOWare Bridge Management software, but also in steering the project from the beginning to address a critical need.

"The whole project panel has been important. They have been positive advocates for a multi-objective approach."

"We had a great panel that contributed a lot to the successful implementation of the project," Johnson says. "The project was defined in terms of what practitioners needed."



Formerly called Pontis, AASHTOWare Bridge Management software is used by most state DOTs to track bridge conditions and make cost-effective decisions.

Thompson notes that 43 of 50 states use AASHTOWare Bridge Management software. "They contribute a license fee," Thompson says, "so it was important to frame this project to address their needs."

Johnson adds, "This project was very timely. It addressed a real-life need that a lot of people were struggling with."

Implementation Success

Ultimately, the improved software will help practitioners make asset management decisions in the most cost-effective ways.

"This project will dramatically improve our method for optimizing bridge projects," Thompson says.

Moreover, the benefits will go well beyond the transportation industry, according to Johnson.

"The concepts that we were researching in this project are broadly applicable methods for modeling and prioritizing needs," he says."The multi-objective optimization framework developed as part of this project has become the current state of the practice in asset management in general, and not just for bridges or the transportation industry."

"This project was very timely. It addressed a real-life need that a lot of people were struggling with."

Deciding when and how to repair bridges can be complex, and it requires prioritizing limited funds. DOTs must take into account not just life-cycle costs but other factors, such as safety, fatigue, and traffic flow disruption.

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How to Minimize Deicing's Environmental Impact

As concern for the environment continues to grow among the public and winter maintenance professionals, NCHRP oversaw development of comprehensive guidelines for selecting environmentally friendly snow and ice control materials. AASHTO implemented these guidelines in a computer-based winter maintenance training program, and other organizations took a proactive role in encouraging their use at the state and local levels.

The winter maintenance community is increasingly interested in minimizing the environmental impacts of deicing chemicals.

Establishing Guidelines to Minimize the Environmental Effects of Winter Maintenance

Every winter, transportation agencies apply large quantities of salt and other chemicals to roads to keep them clear of snow and ice. Rational decision-making guidelines were needed to help maintenance managers assess the properties of various materials and take steps to minimize their environmental effects.

To help meet this need, NCHRP conducted NCHRP Project 06-16 and produced *NCHRP Report 577: Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts* (www.trb.org/Main/Blurbs/158876.aspx). The report provides guidelines through an evaluation of cost, performance, and impacts on the environment and infrastructure.

The project also produced a decision tool for selecting snow and ice control materials to suit the specific needs of any given highway agency (www.trb.org/NotesDocs/NCHRP06-16_MaterialSelectionWizard.zip). The software serves as a purchasing specification and as a quality assurance monitoring program that includes evaluation procedures and standard test methods.

At the conclusion of the research, there was a need to communicate the guidelines and tools to practitioners at state and local transportation agencies.

"This project produced very useful results that needed to be implemented in state DOT training programs," says project panelist Lee Smithson, coordinator for AASHTO's Snow and Ice Pooled Fund Cooperative Program and former Iowa DOT state maintenance engineer. "Training needs included processes for field personnel to assess potential impacts to the natural environment along roadways in their maintenance area, as well as procedures for determining comparative material prices and writing material purchase specifications."

> "A key to implementation of this project was AASHTO taking the lead...."

Paths to Practice

AASHTO computer-based training modules

AASHTO often serves as a critical bridge between NCHRP research and practitioners, and played an especially crucial role in this project, developing a computer-based training program on all aspects of winter maintenance and snow and ice control.

"A key to implementation of this project was AASHTO taking the lead and utilizing expertise from experienced state and local snow and ice control experts to develop these modules," Smithson says.

> "These modules are successfully teaching field and central office maintenance personnel how snow and ice control materials impact the receiving environment."

Self-paced and accommodating multiple learning styles, the program's eight modules can be accessed on maintenance garage computers or via the web. The web-based version was also made Shareable Content Object Reference Model-compliant, allowing integration with state DOT learning management systems.

The AASHTO computer-based training program is in use at nearly all state DOTs,

(continued)

Implementation Strategies AT A GLANCE

- **Partnering with AASHTO to Deliver Training:** Results were used to create computer-based training modules on all aspects of winter maintenance and snow and ice control.
- **Facilitating State and Local Implementation:** The American Public Works Association and the National Association of County Engineers helped incorporate results into the winter maintenance training programs of state and local agencies.
- **Disseminating Results:** Panel members presented results at conferences, symposia, and AASHTO meetings.
- **Framing Research for Practitioner Use:** Implementation was a key consideration in developing research goals.

according to Smithson. The American Public Works Association (APWA) and the National Association of County Engineers (NACE) also include it in their recommended training programs.

> "Implementing results often requires a willingness to accept risks—because sometimes there will be setbacks."

"These modules are successfully teaching field and central office maintenance personnel how snow and ice control materials impact the receiving environment, and how to recognize and rank these impacts," Smithson says.

Facilitating state and local implementation

While AASHTO took the lead in making the guidelines and tools available nationally, APWA and NACE led implementation efforts at the state and local levels.

Chlorides from deicing salts can cause leaf burn—discoloration and decay in plant tissues—and other environmental effects.

"There were many marketing champions from both APWA and NACE," Smithson says. "APWA incorporated research results into its certification program, and some state DOTs made the guidelines a requirement in their training programs."

Ultimately, implementation of research depends on state and local agencies being proactive, according to Smithson, and sometimes this requires a change in culture. Michael Fitch, project panel member and associate principal research scientist at the Virginia Center for Transportation Innovation and Research, agrees. "There are risks involved with changing the way you do things," Fitch says. "Implementing results often requires a willingness to accept risks—because sometimes there will be setbacks." Fitch advocates seeing such setbacks not as failures but as stepping stones to meaningful change.

Overcoming this resistance, according to Smithson, requires advocates within the agencies themselves to show that the potential benefits are worth the risks. "The money and support are out there," Smithson says. "It's just a matter of convincing people there are achievable outcomes that produce savings and improve customer service."

Disseminating results

Disseminating results is critical to such advocacy and overcoming resistance at all levels—national, state, and local. "The more that agencies stay informed and key leaders stay current with research, the more likely implementation is to be successful," Smithson says.

However, there's still a risk, notes Fitch, that key decision makers won't have the time to read lengthy reports. "*NCHRP Report 577* is a big document," Fitch says. "It's crucial that this really important research be boiled down into summaries and highlights so it's accessible to leaders who are pressed for time."

Also critical is presenting findings to fellow practitioners. Smithson himself wrote technical papers about the computer-based training program and presented them at conferences and symposia, including Transportation Association of Canada Annual meetings, PIARC in Sweden, SIRWEC in Finland, AASHTO Highway Subcommittee on Maintenance summer meetings, and various regional snow conferences for APWA and state DOTs.

There is evidence that such efforts have led to *NCHRP Report 577* having a significant reach within the transportation community. "The report is commonly referenced in other research designed to reduce the impacts of winter maintenance practices on the environment," Fitch says. "It is also very commonly mentioned among DOT winter maintenance experts."

> "There were many marketing champions from both APWA and NACE."

AASHTO's computer-based training program uses animation, video, and pre- and post-assessment to foster environmentally aware decision making.

Keys to Implementation Success

In the end, successful implementation of *NCHRP Report 577* depended on multiple channels—from AASHTO, APWA, and NACE involvement to aggressive dissemination efforts and proactive engagement by state and local agencies.

> "The more that agencies stay informed and key leaders stay current with research, the more likely implementation is to be successful."

Fitch also believes that the way the research project was framed from the beginning was critical to its implementation success. "You have to ask the right questions from the get-go to optimize chances for implementation," he says. "That's something the excellent research team for this project did very well."

Smithson agrees, noting that the report served as an excellent foundation for the development of computer-based training.

"When the project started, I was hoping for a broad foundation in the subject area that could be made understandable to field and central office personnel," Smithson says. "That's exactly what we got."

Fitch concludes, "I felt really good about this project, because I saw a product that could clearly serve as a critical foundation to implementation on both the operations and research sides of organizations."

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Putting Flowable Fill Guidance to Work

National interest in an alternative fill material prompted NCHRP research to establish recommendations for its use. Two state transportation agencies—Texas and Indiana DOTs—describe how they turned those recommendations into state practices.

Addressing Gaps in Knowledge and Practice for Flowable Fill

Flowable fill (also called controlled low-strength material, or CLSM) resembles plastic concrete and shares many of the same components: water, cement, fine aggregate, and fly ash. Flowable fill is something altogether different, though. It is an innovative low-strength building material that can serve as an alternative to compacted granular fill on highway construction projects.

Many state transportation agencies see the advantages of flowable fill compared with traditional fill materials and techniques, including improved performance and marked reductions in labor costs. While some states have used flowable fill to a limited extent, its wide use nationally has been held back by knowledge gaps in design, construction, and expected performance.

Moreover, because flowable fill is not governed by AASHTO specifications, it has been left to each state to determine whether to use it, and if so, how. States shared a common need for better understanding of this construction material.

> "Having a process in place to share input and make recommendations really helped move implementation along."

This led to NCHRP Project 24-12(01) and the resulting product, *NCHRP Report 597: Development of a Recommended Practice for Use of Controlled Low-Strength Material in Highway Construction* (www.trb.org/Publications/Blurbs/156851.aspx).

The NCHRP recommendations were an important step toward achieving technical uniformity among states. The guidance includes standardized terminology, strain criteria, and performance testing for flowable fill.

However, significant effort was still needed to put the findings into practice among individual DOTs. As valuable as research findings are as a starting point, state agencies cannot simply "copy and paste" them into their specifications.

Flowable fill is self-leveling and self-compacting. It requires less labor than traditional fill materials.

Paths to Practice

From research results to know-how

Tommy Nantung, a panelist for NCHRP 24-12(01) and pavement materials and construction research manager with Indiana DOT, played a role in helping adapt the NCHRP findings for Indiana's use. One of his duties was to serve as an expert practitioner, bridging the gap between the researchers and the Indiana implementers. As both a project panelist and seasoned practitioner, Nantung helped interpret the technical findings and translate them into practical, useful information.

> "We used the NCHRP product as a jumping-off point for our own in-house research and development."

The job involved sharing his expertise with the right people in the state. As an active member on an Indiana DOT technical committee that addresses construction materials, Nantung was able to bring the NCHRP findings to the steering committee and discuss how to incorporate them in Indiana. "Having a process in place to share input and make recommendations really helped move implementation along," Nantung says.

The implementation process in Indiana included trying out a special provision in the field and gaining a comfort level with new procedures and technologies before making specification changes.

In the end, the state specifications were significantly different from the language in the NCHRP report. Those differences are

(continued)

Implementation Strategies AT A GLANCE

- **Drawing on the Research Team to Apply Findings:** Expert practitioners and the principal investigator helped tailor results to meet DOTs' needs.
- **Ensuring Stakeholder Buy-In:** DOTs collaborated with internal technical committees and supported contractors and regional field staff.
- **Verifying Findings in the Field:** Pilot projects fine-tuned research results and demonstrated benefits.
- **Addressing a Clear Need:** The technology advanced goals for rapid construction and improved fill performance.

all based on real-world field experiences and feedback from practitioners in the state.

Investigators go above and beyond

Another NCHRP project panelist was Texas DOT's Mike Arellano, who was serving in the agency's geotechnical section at the time this research was completed. Arellano points out that Texas DOT, like Indiana, did its own work on the NCHRP findings. "We used the NCHRP product as a jumping-off point for our own in-house research and development," he says.

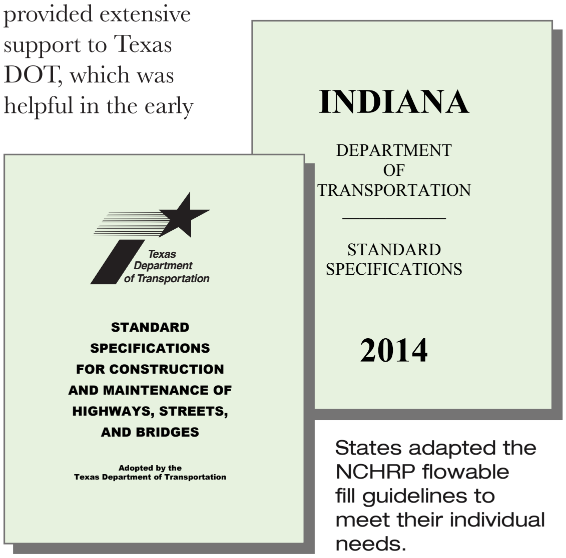
> "In our field trials, we helped suppliers calibrate their gauges and provided the necessary materials."

Texas DOT found the testing guidelines and material designs in the NCHRP report to be particularly helpful. From there, the agency adapted the material properties for the applications it had in mind for rapid set flow fill (Texas' term for flowable fill).

As part of the specifications development process, Arellano pointed out a unique resource that Texas DOT was able to use to its advantage: the principal investigator for the original NCHRP research.

"With many NCHRP projects," Arellano explains, "the researcher's job is done when the report is accepted. In this case, though, we had the good fortune of having the principal investigator, Kevin Folliard of the University of Texas at Austin, right in our backyard."

Folliard and his team provided extensive support to Texas DOT, which was helpful in the early stages of implementation. The investigators sat down with the agency and provided assistance throughout the field investigations.


INDIANA
DEPARTMENT OF TRANSPORTATION
STANDARD SPECIFICATIONS
2014

Texas Department of Transportation
STANDARD SPECIFICATIONS FOR CONSTRUCTION AND MAINTENANCE OF HIGHWAYS, STREETS, AND BRIDGES
Adopted by the Texas Department of Transportation

States adapted the NCHRP flowable fill guidelines to meet their individual needs.

> "We finalized [the standard specification] a few years ago, and we're happy with it now and with the results we're seeing."

Giving stakeholders the support to succeed

State agencies recognize that implementation cannot succeed through the efforts of central office staff alone. Ensuring buy-in from private industry and regional DOT staff alike is critical.

If a DOT were to write new flowable fill specifications but not secure industry support, then those specifications likely would not work. It is critical to reach out to the ready mix concrete industry to explain—and provide a rationale for—new procedures and policies.

At the same time, it is necessary to make sure that materials engineers who oversee fieldwork are fully prepared to meet the requirements of new specifications.

In Texas, Arellano conducted outreach efforts to ensure success in the field. He noted that one potential difficulty involved the supply of rapid set flow fill material. "In our field trials, we helped suppliers calibrate their gauges and provided the necessary materials," Arellano says. At the same time, the agency did quite a bit of testing on its own to validate the results of this construction method.

Implementation Success: A New Tool in the Toolbox

The hard work toward full implementation has paid off. Texas DOT saw the success of a few pilot projects in San Antonio that made use of its new specifications. From that point on, rapid set flow fill became a standard option to repair bridge approaches in Texas. Arellano notes that the alternatives, reconstruction or full-depth repair, are heavy and contribute to consolidation. Flow fill is a lightweight alternative that can still handle the heavy bridge loads.

Arellano also cites the advantages of flow fill for accelerated construction. In one example in the Austin district, the agency had an intersection to rebuild over a weekend, and it used rapid set flow fill as an accelerated method. "It's a very useful tool to have at our disposal," Arellano says.

The technology has become standard procedure in Indiana as well. Nantung describes an iterative process. "We went from a special provision to a standard specification," he says, "and then through 12 versions of the specs, tweaking it every step of the way. We finalized it a few years ago, and we're happy with it now and with the results we're seeing."

Indiana DOT's Pavement Steering Committee serves as a forum for agency practitioners to evaluate how NCHRP findings may meet the state's needs.

Indiana and Texas are two good examples of implementers, but they are not alone. Nantung points out other examples: "Colorado does a lot of flowable fill, as does Ohio. I think across the country, states are using flowable fill—or using it more—thanks to this NCHRP research."

> "Across the country, states are using flowable fill—or using it more—thanks to this NCHRP research."

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NCHRP Reports 572 and 672

Research Makes the Case for Roundabouts

Roundabouts clearly provide safety and mobility benefits, yet some transportation agencies in the United States have been slow to adopt them. NCHRP research established foundational knowledge on roundabout safety, operation, and design that has driven a surge in their use nationwide.

Roundabouts, which help increase safety and reduce congestion, are becoming more common in the United States through the implementation of NCHRP Project 03-65.

Roundabouts in the United States: A Need for Data

In the 1950s, traffic circles fell out of favor in the United States because they allowed for high-speed merging and weaving of vehicles. A remedy for this unsafe and inefficient design was developed overseas: The United Kingdom developed the modern roundabout design that slows entering vehicles and requires them to yield to circulating traffic.

> "Virtually everything that came out of *NCHRP Report 572* worked its way into the roundabout guide."

This design is generally more efficient than traditional intersections, typically reducing congestion by keeping traffic flowing. It is safer as well, minimizing traffic conflict points and reducing the right-angle crashes that lead to more severe injuries and fatalities.

Because of these benefits, modern roundabouts are now widely used internationally. However, the United States has been slower to accept roundabouts because of questions about safety and operational capacity.

To help address such questions, NCHRP Project 03-65 was conducted, which resulted in *NCHRP Report 572: Roundabouts in the United States* (trb.org/news/blurb_detail.asp?id=7086). Researchers inspected several representative roundabout installations to gather data and compiled a comprehensive inventory of roundabouts in the United States.

The resulting report includes methods for estimating the safety and operational capacity of roundabouts as well as updated design criteria. Technical guidance is spelled out in detail in the companion appendices, *NCHRP Web-Only Document 94* (trb.org/news/blurb_detail.asp?id=7274).

Paths to Practice

Incorporation into widely used tools

The results of NCHRP 03-65 have been incorporated into a number of widely used tools, including *NCHRP Report 672: Roundabouts: An Informational Guide—Second Edition* (trb.org/Publications/Blurbs/164470.aspx). This report is an update to an FHWA guide originally published in 2000, one based primarily on European and Australian guidelines.

"Virtually everything that came out of *NCHRP Report 572* worked its way into the roundabout guide, *NCHRP Report 672*," says Lee Rodegerdts, the principal investigator who authored both *NCHRP Reports 572* and *672*. "This is a go-to source nationally for information on roundabouts and is also being used outside of the United States."

> "With the help of FHWA, TRB, and other agencies, we were able to get our results into key documents used nationally and internationally."

The roundabout capacity model and operational information developed in *NCHRP Report 572* was also implemented into TRB's 2010 *Highway Capacity Manual* (HCM). "The HCM is widely used by transportation agencies across the United States and can be drawn upon to aid roundabout implementation nationwide," says Rodegerdts, who is also a former HCM committee member and part of the team that updated the 2010 edition. "It's a cornerstone document with a huge audience."

(continued)

Implementation Strategies AT A GLANCE

- **The Basis for National Guidance:** Results were incorporated into a number of widely used manuals and specifications such as *NCHRP Report 672*, TRB's *Highway Capacity Manual*, and AASHTO's "Green Book."
- **Facts Drive Acceptance:** Beyond demonstrating benefits, the research helped identify and dispel misconceptions that act as barriers to implementation.
- **Identifying Additional Needs:** Follow-up projects will improve crash prediction and capacity models, and will address accessibility for the visually impaired. The results will further accelerate implementation.

> "This research is key for states that have challenges with implementation."

Results were also incorporated into AASHTO's *A Policy on Geometric Design of Highways and Streets*, or "Green Book," as well as several state DOT roundabout guides, noted Mark Doctor, FHWA liaison to NHCRP 03-65. "The breadth of its influence is a testament to the wealth of useful information this project produced," Doctor says.

Rodegerdts adds, "With the help of FHWA, TRB, and other agencies, we were able to get our results into key documents used nationally and internationally. That was a critical part of implementation."

Demonstrating safety, increasing acceptance

Part of the importance of *NCHRP Report 572* is how it continues to drive acceptance of roundabouts by clearly demonstrating their safety benefits. "This is the first large-scale national study to collect field data and make recommendations," Rodegerdts says. "Our safety data are powerful and definitive."

Doctor agrees. "Without a doubt, roundabouts are safer than traditional intersections," he says.

Some of the reluctance to adopt roundabouts in the United States is predicated on public misconception. One common misconception is that a roundabout and a rotary are the same. Rotaries are higher speed facilities and can require changing lanes to exit, making them difficult for drivers to navigate during peak use. Other misconceptions about roundabouts are that they are always more expensive to build than signaled intersections and that they are difficult to learn to navigate. Tools to dispel such myths and provide facts to the public are important for acceptance.

"This research is key for states that have challenges with implementation," Doctor says, "whether in design, or planning, or convincing the public and elected officials that roundabouts are indeed the safer and more cost-effective choice."

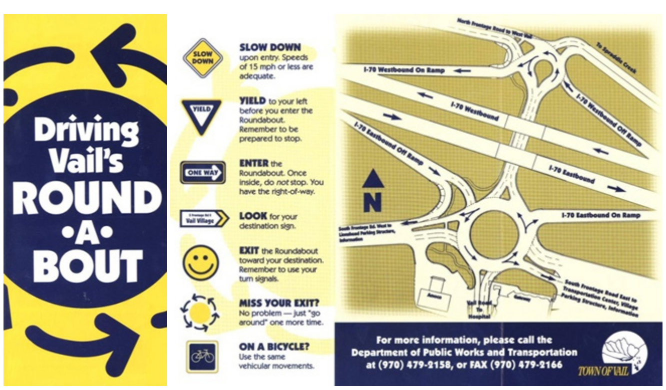
Continued research to accelerate implementation

NCHRP Report 572 has also been the impetus for continued research focused on encouraging implementation. "We're now 10 years removed from the data collected in 2003 for NCHRP Project 03-65," Rodegerdts says. "There were about 300 roundabouts in the United States back then, while now there are closer to 3,000."

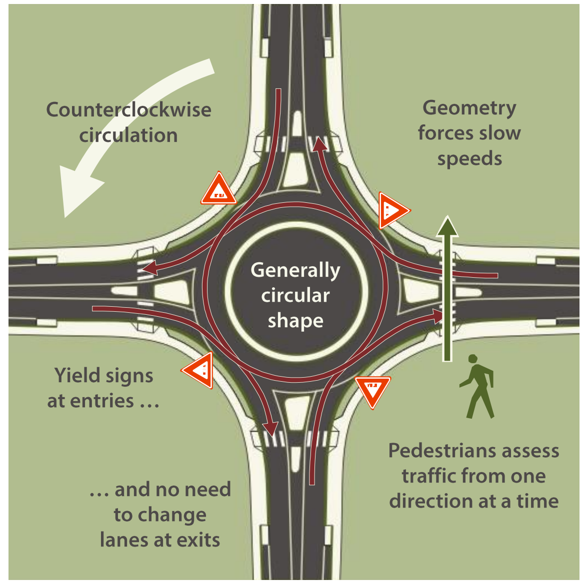
> "There were about 300 roundabouts in the United States [in 2003], while now there are closer to 3,000."

With increasing use of roundabouts, there is also more data—data that can be used to develop more robust capacity and safety models. To that end, NCHRP Project 17-70 is underway to develop roundabout crash prediction models for AASHTO's *Highway Safety Manual*. NCHRP Project 03-78B is addressing the accessibility of roundabouts to visually impaired pedestrians.

In addition, an FHWA-funded project (kittelson.com/projects/fhwa-topr-34-accelerating-roundabout-implementation-in-the-united-states) is focused directly on accelerating roundabout implementation in the United States by updating capacity and crash models with new data. This is an important project for the evolution of roundabout practice because some practitioners are concerned that current models based on *NCHRP Report 572* data do not reflect the operations of roundabouts at full capacity.



Road authorities encourage acceptance of roundabouts by providing guidance to road users who are unfamiliar with them.



Modern roundabouts are designed for safety and ease of use.

"All of these projects are important descendants of NCHRP Project 03-65 that will help with implementation nationwide," Rodegerdts says.

Implementation Success

With *NCHRP Report 572*'s broad and definitive influence, NCHRP 03-65 is a model for successful implementation. "The project has significantly improved roundabout design in the United States and made engineers more comfortable with selecting roundabouts as an alternative to other intersection controls," says project panel member Richard Long, a professor at Western Michigan University with expertise in pedestrian safety. "It also brought to the forefront concerns about access for pedestrians, especially the visually impaired."

> "There was a lot of hunger for practical information. This led to a widely used report that put implementation at the forefront."

Doctor noted that one key to the project's success was a focus on implementation from the beginning. "This was a practitioner-oriented project with very useful results that were bound to change practice," Doctor says.

Long agrees. "There was a lot of hunger for practical information," he says. "This led to a widely used report that put implementation at the forefront."

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Safer Intersections for Rural Highways

Right-angle crashes are a problem on median-separated highways, but the most typical solutions for this problem—constructing an interchange or installing traffic signals—are not always the most effective. NCHRP managed research on safer median intersections that led to the expanded use of innovative designs by state transportation agencies. The effects on safety have been dramatic.

Intersections on Rural Highways: A Serious Safety Risk

Median-separated highways provide distinct advantages over undivided roadways by separating traffic, providing a recovery or stopping area for vehicles, and providing space for left-turn vehicles. In many cases, they also provide the same safety and travel time benefits as rural interstates at a lower cost. However, these safety benefits can be diminished by an increase in the frequency and severity of intersection crashes, especially right-angle crashes that occur while a vehicle from a minor road is making a left turn through the median and onto the highway.

J-turns significantly improve rural highway intersection safety by preventing drivers from directly crossing medians and requiring them instead to make a right turn followed by a U-turn.

Because interchanges and traffic lights are not always the most effective or cost-efficient solutions to these problems, transportation agencies are in need of innovative, low-cost designs that can be used to improve the safety of such intersections. To help establish design guidance and safety data for these treatments, NCHRP Project 15-30 was undertaken, resulting in *NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways* (www.trb.org/main/blurbs/163452.aspx).

> "In the past, options for improving safety at high-speed rural safety intersections were limited."

The report includes 10 case studies illustrating how various intersection designs have been applied in the field and includes recommendations for updating guidance in the FHWA *Manual on Uniform Traffic Control Devices* and AASHTO's *A Policy on Geometric Design of Highways and Streets*, or "Green Book."

Paths to Practice

An expanded toolbox for state DOTs

NCHRP Report 650 showed that many of the intersection designs examined can significantly improve safety at a lower cost than constructing an interchange. In doing so, the report gives states an expanded set of options for dealing with problem intersections.

"In the past, options for improving safety at high-speed rural intersections were limited," says Tom Welch, panel chair for NCHRP 15-30 and formerly a highway safety engineer for the Iowa DOT. "Options included a new interchange, which involves major new spending, or installing a traffic signal, which is not guaranteed to improve safety and may even worsen it."

According to Welch, *NCHRP Report 650* provides engineers with everything they need to make an informed decision about how to handle a problem intersection and how to approach the task of design. "With this report, we have a good toolbox," Welch says. "There is no missing information."

J-turns: States adopt a safer intersection design

One of the median treatments examined in *NCHRP Report 650* is the J-turn intersection, which prevents a driver on a minor road from directly crossing the median. Instead, drivers are forced to make a right turn and subsequently a U-turn at some distance from the intersection. Because the J-turn reduces drivers' exposure to oncoming traffic in the opposing lane, the distance of which can be difficult to judge, the safety benefits can be significant.

> "The J-turn is the main tool we consider when we need to address right-angle crashes."

"Our case study showed that J-turns produced a 48 to 92 percent reduction in

(continued)

Implementation Strategies AT A GLANCE

- **Cost-Efficient Solutions:** *NCHRP Report 650* spells out rural intersection solutions that increase safety benefits and lower costs. This offers DOTs a fast track to implementation.
- **Addressing a High-Profile Research Need:** DOTs have expressed keen interest in these solutions, and research-based guidance supports field trials and implementation.
- **Proof for the Public and Elected Officials:** Research data and supporting materials help satisfy members of the public and lawmakers who need evidence that these new designs work.

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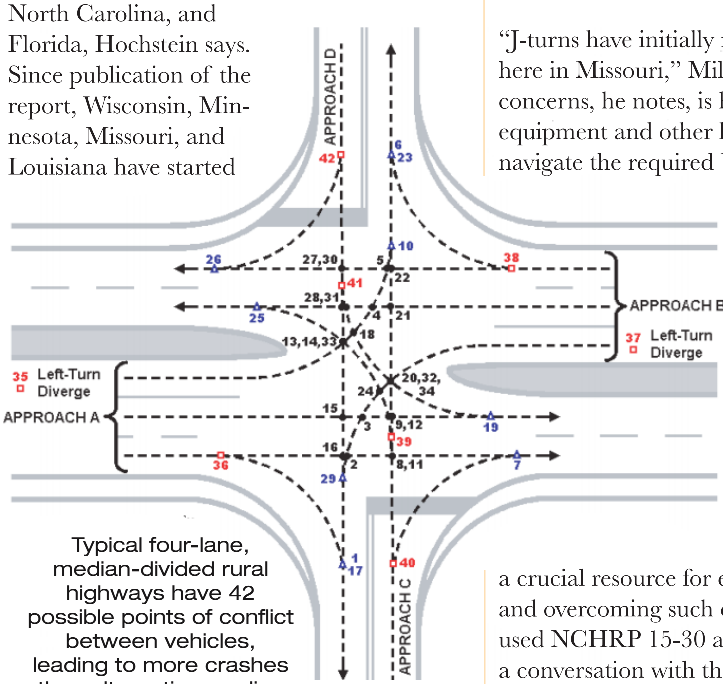
crashes, and as much as a 100 percent reduction in more severe right-angle crashes," says Joshua Hochstein, study co-investigator and Ph.D. candidate at Iowa State University.

> "With objective safety data, the report lessens the burden of explaining to the public why these treatments are necessary."

By the end of the study, state transportation agencies' interest in J-turns was high. After sharing case studies with agencies during a multistate video conference, researchers had transportation agencies vote on how to prioritize further research into countermeasures. "They voted J-turns to be the highest priority," Hochstein says.

The only states using J-turns when *NCHRP Report 650* was written were Maryland, North Carolina, and Florida, Hochstein says. Since publication of the report, Wisconsin, Minnesota, Missouri, and Louisiana have started using J-turns, and Iowa is considering their use. Minnesota and Missouri are leaders in implementing the treatments, Welch says.



Typical four-lane, median-divided rural highways have 42 possible points of conflict between vehicles, leading to more crashes than alternative median designs like J-turns.

According to Missouri DOT traffic engineer John Miller, Missouri has already installed 12 J-turns with four more in the works. "The J-turn is the main tool we consider when we need to address right-angle crashes," he says.

Minnesota has constructed about six J-turns and is planning six more, according to Brad Estochen, traffic engineer at Minnesota DOT. "For problem intersections with high-speed angle crashes, J-turns are something we can implement to improve the situation far more quickly and cost-effectively than overpasses," Estochen says.

Some J-turn treatment U-turn designs involve bulb-outs to accommodate larger vehicles.

A tool for educating the public

However, implementation of J-turns can be a difficult task, often facing fierce public opposition. Minnesota, Missouri, and Iowa have all reported similar problems.

"Drivers want to know why they can't make a left turn," Estochen says. "This is something new and nontraditional, and the public can be reluctant to embrace change."

"J-turns have initially not been well-received here in Missouri," Miller says. One of the concerns, he notes, is how well agricultural equipment and other large vehicles can navigate the required U-turns. According to Welch, Iowa also encountered early resistance to its consideration of J-turns.

However, Estochen, Miller, and Welch agree that the safety data and case studies in *NCHRP Report 650* can be a crucial resource for educating the public and overcoming such opposition. "We've used NCHRP 15-30 as a basis to start having a conversation with the locals about improving the safety and performance of potentially troublesome intersections," Estochen says. "With objective safety data, the report lessens the burden of explaining to the public why these treatments are necessary. It shows that these treatments, while unfamiliar, have been successfully implemented before."

> "We've seen a 90 percent reduction in angle crashes where we've installed J-turns."

"Because of the public reaction, the NCHRP results are handy," Miller says. "We can point to the large reduction in collisions—and it really helps us sell J-turns."

Implementation Success

Once installed, the safety benefits of J-turns sell themselves. "We've seen a 90 percent reduction in angle crashes where we've installed J-turns," Estochen says. Missouri has had similarly impressive safety results.

> "This is one of the most successful NCHRP projects I've been involved with. I'm proud to be a part of something that has saved lives."

Estochen notes that *NCHRP Report 650* is a tool not just for educating the public, but also engineers—both new and seasoned—about alternatives to interchanges.

Miller and Welch agree. "This is a really important report," Miller says. "It's one I actively share with other staff."

"This is one of the most successful NCHRP projects I've been involved with," Welch says. "It really identified a need that states had, and I'm proud to be a part of something that has saved lives." Ultimately the results will be incorporated into AASHTO's Green Book and the FHWA *Manual on Uniform Traffic Control Devices*, he says.

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