

Minnesota Department of Transportation RESEARCH SERVICES 2008 Annual Report





The purpose of this report is to meet the requirements set forth by the Code of Federal Regulations, Part 420—Planning and Research Program Administration—420.117 2(e):

"Suitable reports that document the results of activities performed with FHWA planning and research funds must be prepared by the State DOT or subrecipient and submitted for approval by the FHWA Division Administrator prior to publication. The FHWA Division Administrator may waive this requirement for prior approval. The FHWA's approval of reports constitutes acceptance of such reports as evidence of work performed but does not imply endorsement of a report's findings or recommendations. Reports prepared for FHWA-funded work must include appropriate credit references and disclaimer statements."

For more information, please visit:

Minnesota Department of Transportation: http://www.dot.state.mn.us/ Mn/DOT Research Services Section: http://www.research.dot.state.mn.us/ Mn/DOT Library: http://www.dot.state.mn.us/library/ Minnesota Local Road Research Board: http://www.Irrb.org/

Minnesota Department of Transportation

RESEARCH SERVICES 2008 Annual Report



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Acknowledgments

The Minnesota Department of Transportation's research and implementation efforts involve many researchers and transportation practitioners throughout Minnesota and other states. We would like to recognize the ongoing efforts of these individuals to improving Minnesota's transportation system.

Thank you to the following individuals for contributing their time and knowledge to the project Technical Summaries and other elements in the *Mn/DOT Research Services 2008 Annual Report*.

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Special thanks to the Minnesota Local Road Research Board, Federal Highway Administration, Minnesota Local Technical Assistance Program and the University of Minnesota Center for Transportation Studies for their fruitful cooperation with Mn/DOT to enrich and communicate our research and implementation efforts.

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Director's Message

Welcome to the 2008 annual report of the Mn/DOT research program.

We are pleased to present the projects, products and services that have brought innovation to the state's transportation system. The efforts of investigators, consultants and Mn/DOT staff have been instrumental in advancing the aggressive goals adopted under Commissioner Thomas K. Sorel for meeting the needs of the public in a cost-effective manner.

This document represents our accountability to Mn/DOT's leaders and district offices, to the Local Road Research Board and the agencies that drive its agenda, and to Minnesota's taxpayers. Our innovation and technology transfer activities support Mn/DOT and local governments in the stewardship of the funds they receive; the innovations we deliver help maintain and further develop Minnesota's transportation infrastructure, supporting not only our highway and bridge system, but also our local roads and highway alternatives such as transit. Our programs are also critical to increasing the safety of Minnesota travelers, as well as their confidence in Mn/DOT.

Key elements of this publication include the following:

- In the opening pages, we present the services of the Mn/DOT research program and library, a staff listing, an overview of our goals and activities, and a description of our partnerships and programs.
- In the back of the report, you will find *Mn/DOT Research At-A-Glance*, which lists by funding program all of our completed research and implementation projects as well as projects currently in progress and the pooled fund projects in which Mn/DOT participates.



• The bulk of the annual report is composed of two-page Technical Summaries for most reports completed in 2008, organized by those produced by the LRRB and those supported by state and federal

research. An overview of each of these programs precedes the respective Technical Summaries.

2008 brought with it the development of several innovations that will help us achieve our goals for 2009 and beyond. Chief among these was the introduction of a cross-functional research strategy, highlighted by implementation of:

- · Strategic Vision for Research: Eight cross-departmental focus areas for research
- · Innovation Roadmaps: Plans that delineate where we're going with research before we get there
- End-User Products: Specific goals for readily usable research outcomes
- Transportation Research and Implementation Group (TRIG): A management group brought together to maximize Mn/DOT's return on investment through improved project selection and strategic research planning

2008 has marked a time of transition for Mn/DOT's Research Services Section with its incorporation into the new Office of Policy Analysis, Research and Innovation. This reorganization is a key part of Commissioner Sorel's vision that will make Mn/DOT one of the country's leaders in innovation, creativity and strategic investment.



We are pleased to present the projects, products and services that have brought innovation to the state's transportation system.



2009 will be an exciting and challenging time for the Research Services Section. Innovative solutions for managing and improving Mn/ DOT's research program will be brought online to help us fully implement the Strategic Vision for Research (conceived in July 2007) and to help complete Commissioner Sorel's vision. Innovations for 2009 will include:

- A new, more descriptive and customer-focused name for the Research Services Section (stay tuned!)
- ARTS 2.0 (Automated Research Tracking System) Our nextgeneration system for managing research funds and projects
- A more aggressive, results-oriented approach to marketing the improvements our research and innovation can make to Mn/DOT and the state of Minnesota
- · An increased focus on technology transfer and communications

Please consider this document an invitation to inquire further about any of the projects described, and to make more extensive use of our innovation and information professionals to help you do your job more easily and effectively. We welcome your suggestions, comments and questions. Our research program will continue to bring innovation to Mn/DOT and to the state of Minnesota with the support and contributions of Mn/DOT staff, the LRRB, the Federal Highway Administration, and our partners at universities and other public and private organizations.

SUE LODAHL Director, Mn/DOT Research Services Section sue.lodahl@dot.state.mn.us

Mn/DOT Research and Library Services



Most Research Services staff members are headquartered at the Mn/DOT Transportation Building in St. Paul. The mission of Research and Library Services is to help Mn/DOT staff do their jobs—through both daily support of their research and information needs as well as longer range efforts to help realize the innovation goals of Mn/DOT and the LRRB. With the help of our university and consultant partners, we pursue practical innovations that will be valuable and useful to transportation practitioners throughout Minnesota. We also participate in national research programs to ensure that Minnesota's interests are well-represented in these efforts and that Mn/DOT staff members are made aware of the latest innovations and best practices for improving safety and saving taxpayer money.

We fund innovation needs throughout the year. Our Web site includes a "Submit an Idea" page. We solicit proposals for potential research projects from academic research institutions in September and October of each year. Our participation in national research efforts and our multiple funding sources afford several avenues for addressing research priorities.

Leadership

Mn/DOT Research Services, under Sue Lodahl's leadership, is responsible for the day-to-day operations of both Mn/DOT's and LRRB's research programs. As director of Research Services, Lodahl is the liaison to upper management, other Mn/DOT offices and external customers. She is an LRRB board member, serves as Mn/DOT's

representative to the Transportation Research Board and AASHTO's Research Advisory Committee, and is a member of many other steering and advisory committees.

Mn/DOT's leadership has identified eight strategic topics for research, as described in "About Mn/DOT's State Research Program" and the *Mn/DOT Research At-A-Glance* guide. The role of Research Services management is to provide ongoing input about the status of these topics and to ensure that these strategic priorities direct research activities. This involves such measures as directing the creation and ongoing development of innovation roadmaps, a process which we are working to extend into the operations of LRRB. It is also management's role to lead Research Services through its transition in to the new Office of Policy Analysis, Research and Innovation. This includes reorganizing staff and ensuring that defined staff roles are adequate to meet the challenges of the coming years.

Research Identification and Management

Mn/DOT Research Services staff members help identify innovation needs throughout the department, using Mn/DOT's innovation roadmaps and other criteria to determine what problems can best be addressed through formal research investigation, and managing many of the individual innovation roadmaps that link families of related projects. Research staff coordinates projects for Mn/DOT's and LRRB's research programs, and also coordinates with state and national cooperative research programs, including the Transportation Pooled Fund Program.

Administrative liaisons to research projects ensure that contracts are followed and that deliverables are submitted and approved, working with technical liaisons from Mn/DOT or Minnesota counties to manage and evaluate projects through their entire life cycle, from contracting through implementation and technology transfer.

Research Implementation, Outreach and Technology Transfer

Staff members analyze completed Mn/DOT and LRRB research for potential implementation actions to enable practical application. They act as administrative liaisons to implementation projects or other implementation efforts. These staff members are increasingly involved with research (and the innovation roadmaps being used to organize research) right from the start, to help determine implementability and ensure that effective implementation steps are built into contracts. They identify the impacts of research investments and measure performance of individual projects and evaluation of Mn/DOT's research program as a whole.

Research staff members are responsible for communications planning, marketing and outreach for Research Services and LRRB. They coordinate publication of research reports, brochures, instructional videos, software and manuals. They engage in a variety of technology transfer activities, both as a part of implementation projects and for the program as a whole. They create project summaries, research syntheses, the Innovation Presentation Series, program reports and a bimonthly newsletter; maintain the Research Services and LRRB Web sites; and, in conjunction with the Local Technical Assistance Program, facilitate training efforts to help maximize Mn/DOT's research investments.

Staff members maintain contact with clients through visits with district staff, participation on project Technical Advisory Panels and regularly scheduled events such as quarterly LRRB and Research Implementation Committee meetings; the annual Implementation Funding Program; the annual Spring Maintenance Expo; the TZD Conference; and other state, city and county conferences held throughout the year.

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Library and Information Services

The Mn/DOT Transportation Library, under the new management of Sheila Hatchell, brings together the information resources and services required to provide timely access to information needed by Mn/DOT staff and partners who plan, design, build, operate and maintain the state's transportation infrastructure.



Library staff members assist Research Services in identifying existing research in a given area to help ensure that all projects proceed with a firm foundation and to avoid duplication of effort. They help patrons navigate electronic resources and answer ad hoc information queries that help engineers and managers efficiently make money-saving decisions. Library staff members also collect and catalog reports and other information resources produced by Mn/DOT for inclusion in databases accessed by researchers worldwide.

The Library serves as a vital resource for both Mn/DOT staff and outside investigators. As an element of LTAP, in collaboration with the University of Minnesota's Center for Transportation Studies and the Minnesota Transportation Libraries partnership, the Library's resources and services are made available to transportation officials and practitioners throughout the state. The Library further participates in local and national partnerships and networks such as the Transportation Library Connectivity Pooled Fund, the Capitol Area Library Consortium, the Midwest Transportation Knowledge Network, the Special Libraries Association Transportation Division, MINITEX, Mn/ PALS (a library catalog consortium) and the Online Computer Library Center, providing Mn/DOT access and shared information resources on local, state, regional, national and international bases.

Financial Services

The Financial Services group, under the guidance of Ann McLellan, coordinates research contracts and funding processes, including contract creation; budget management; and local, state and national research funding coordination. This group handles purchasing for the department, including travel arrangements for meetings and conferences.

Research Services staff members are experts on the various funding sources available for research, and help Mn/DOT and (through LRRB) local practitioners and managers determine the most appropriate sources of funding for the research they need enacted.

Information Technology

IT specialist Nelson Cruz and other support staff provide programming, analysis and project management for databases and other tools that support the research programs. They provide technical consultation on IT projects, including IT implementations resulting from research projects.

Administrative Support

All of these processes require prompt and flexible administrative support. Staff members in the Research and Library areas deliver the organizational and logistic services necessary for smooth operation of research management, departmental systems, publication activities and events.

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Research Services 2008 Accomplishments and Initiatives

Number of active research projects in 2008: 237 Number of completed reports and implementation products in 2008: 63



2008 Funds Expended

State Research Program:	\$2,332,518
LRRB:	\$2,569,194
FHWA State Planning and Research:	\$4,785,184
Total:	\$9,686,896



A Strategic Transition: Highlighted 2008 Initiatives

2008 has been a time of transition for Mn/ DOT's Research Services. With its incorporation into the new Office of Policy Analysis, Research and Innovation, Research Services has assumed a broader role for research within Mn/DOT that will help the department continue its national leadership in innovation, creativity and strategic investment.

As part of the transition, Research Services is employing a cross-functional research strategy that implements innovation roadmaps and changes in organizational structure to support a number of innovations described in the following sections.



Innovation Roadmaps: A More Strategic Approach to Projects

In 2007, Research Services introduced a more strategic approach to developing Mn/DOT's annual research and innovation program. Now Research Services is using a planning process called "roadmapping" to define where a research project is headed before it gets there.

Instead of focusing on problems, innovation roadmaps focus on the solutions needed by end users. Innovation roadmaps also anticipate a set of related projects required to develop and deploy end-user products, such as new specifications, software applications and other types of tools useful to transportation practitioners.

Innovation roadmaps also identify the need for additional action after a project is completed. For example, ensuring that the results of a research project improve Mn/DOT's infrastructure or services may require product development, changes in policy, new training, budgetary decisions and other actions.

By focusing on the interrelations between projects and using cross-functional focus groups to identify end-user products, innovation roadmaps will help reduce the "silo effect" that often hinders departmentwide implementation of innovations. Roadmapping will also be highly useful to the LRRB, providing valuable continuity to its quarterly meetings and supporting its emphasis on implementation and applied research.

Supporting Innovation Roadmaps: Changes in Organizational Structure

The new strategic focus for research and innovation will require new business processes as well as a new organizational structure to implement these processes.

Research Services will use roadmap managers within specific technical and strategic areas to act as problem solvers, remove barriers to roadmap goals and work with clients that serve as roadmap champions.

Meanwhile, Research Services staff will continue to manage and monitor program areas at a broader strategic level, and administrative liaisons will continue to administer projects with direction from the client technical liaison.

Whether Research or Implementation, a Project is a Project



Research Services will no longer distinguish research projects from implementation projects, but instead focus on delivering projects that are useful to end users and promote innovation.

Because there is so much uncertainty within the research community itself over the distinction between research and implementation projects, Research Services has concluded that for administrative purposes, a "project is a project." Innovation roadmaps

Innovation roadmaps cover all strategic areas, including infrastructure preservation (including protecting Minnesota's bridges), green construction, congestion management and multimodal strategies. will place projects on a continuum ranging from ideas to full deployment. In turn, roadmap support documents, such as end-user product descriptions and implementation plans, will identify the steps necessary for reaching full deployment (for example, training and equipment upgrades).

Experience has shown that innovation roadmaps need to be flexible enough to adapt to continuing developments in knowledge, priorities, policies, funding availability, departmental priorities and other issues faced by Mn/DOT. Referring to all projects as projects will help Research Services focus on innovation.

Improved Technology Transfer and Customer Outreach

Research Services has stepped up its communications efforts with expanded annual reporting; a LRRB-specific *At-A-Glance* product; and our flagship technology transfer product, the two-page Technical Summaries that make up the majority of this report. Designed to be readable by nonspecialists yet useful to experts, these summaries provide a quick glimpse into most projects from 2007 onward. To further improve customer outreach, Research Services has produced an expanded and redesigned Web site to make it easier to find out what research is taking place and how to interact with the department.

Other Innovations to Improve Research Services

Other Research Services innovations for 2009 will include:

- Launching the Innovation Presentation series, which will include monthly presentations of current research to management and practitioners.
- Updating the ARTS project management system to ARTS NG, which will give Research Services a better tool to document and track the progress of innovation roadmaps and projects, as well as the contract

and financial information that ARTS was originally designed to track. ARTS NG will also include protocols for data entry standards and enforcement.

- Speeding up processes for certain efforts so that
 other initiatives and customer satisfaction are not
 compromised. Areas for improvement include the
 dissemination of seminar results, IT support, "quick
 hitting" research for hot topics, transportation
 research syntheses and funding panel evaluations.
- **Contracting with consultants** to work closely with Research Services customers, tailoring literature searches and other search requests to specific needs, and performing literature reviews on broader roadmap topics. While Research Services is fortunate to have a library staff that can provide top-quality literature searches on any transportation-related topic, the staff does not have the time to deliver a full range of reviews for all Research Services customers.
- **Defining administrative liaison duties more clearly** to ensure that there is consistency in recordkeeping and that the Technical Advisory Panel leads the project to the outcome defined by the roadmap. Administrative liaison duties may need to be distinguished from high-level program management support of innovation roadmaps.
- **Establishing performance measures** to demonstrate the value of innovation and the regular improvement of innovation processes. Roadmap managers will use data from Consultant Performance Evaluation forms as decision-making tools for determining next steps, selecting contractors and establishing new performance measures. They will also analyze current evaluation data and update form questions to collect performance measure data relevant to innovation roadmaps.

Highlighted Trends in Research

Bridge Design and Maintenance. Research Services is engaged in several efforts dedicated to ensuring the integrity and longevity of Minnesota bridges. Mn/DOT is committed to rigorous testing to improve design specifications and ensure ongoing performance levels. In one recent study (**Report 2008-47**), researchers continued monitoring the long-term performance of epoxy-coated reinforcing bars; the coating serves to protect the bridge's steel reinforcing bars against corrosion by chlorides in deicing chemicals.

Safety Analyses. Mn/DOT is dedicated to reducing the number of traffic-related fatalities, and several research projects have aimed to help us better identify the most pressing safety issues and determine how best to target countermeasures. One study (**Report 2008-17**) evaluated the costs and benefits of constructing highway median barriers on the divided four-lane highways where cross-median crashes have taken hundreds of Minnesotans' lives.

Intelligent Compaction. The long-term performance of our roads depends on the stability of underlying subgrade and base layers. This requires compaction and quality control methods to ensure that compaction has been sufficient. Mn/DOT is engaged in a comprehensive effort to upgrade roller and quality assurance technologies to improve compaction



Mn/DOT is working to further develop intelligent compaction, which involves rollers equipped with sensors that continuously measure subgrade stiffness and automatically adjust compaction force accordingly.

precision in a wider range of environments and to use the process to collect performance data that will help improve design and construction practices.

Environmental Protection. Mn/DOT and local transportation agencies are responsible for managing roadside vegetation and mitigating the effects of vehicle and deicing chemical waste on the environment.

One project (Report 2008-20) involved updating the *Best Practices Handbook for Roadside Vegetation* to address current concerns, including how to preserve roadside habitats without compromising driver safety.



Implementation. Research Services is committed to creating products with immediate application to current practices to save lives and money. This includes leveraging completed research to create workshops, handbooks, specifications and other tools for use by Mn/DOT districts, counties and cities. One recent project (**Report 2008RIC06**) produced workshop materials covering best practices and new technologies in street sweeping to help local agencies choose solutions to suit their particular needs and budget.

Updated Tools and Information. Transportation professionals need more readily available information, which means combining existing data stores, making information accessible over the Web and increasing users' power to manipulate data to produce tangible results. Recent projects have helped to track pavement test sections, vehicle crashes, bridges, pavement marking records, land survey and surface water information, and other data. Street sweeping is vitally important to roadway appearance and maintenance, air and water quality, and safety. Local agencies needed a guide to the available technology options.

Mn/DOT Library 2008 Accomplishments and Initiatives

In 2008, the Mn/DOT Library continued to provide vital services to the Department. Key measures for the year included:

- Patrons served: 608
- Items circulated: 2,438
- Reference questions answered: 1,344
- Interlibrary loans: 584
- Periodical issues routed: 14,657
- Literature searches: 557



This year, the Library expanded its services, publicized them to new customers within and outside of Mn/DOT, and received recognition for its excellence in both its Web presence and for the service and facilities at its convenient first-floor location in the Mn/DOT Transportation Building.

Expanding Services

The Library's most important project this year involved creating a dedicated facility for research into the I-35W bridge collapse. This Bridge 9340 Research Area includes two workstations to provide the public with access to

Friendly and efficient, Mn/DOT Library staff are information experts capable of saving engineers and other staff a tremendous amount of time and duplicated effort. e-mail and scanned and electronic documents related to the entire history of the bridge—from its construction to the investigation of its collapse.

The Library also launched a new monthly publication, *New Library Materials*, which notifies customers of recently acquired materials as soon as they are received. Each issue includes tips for online research, with topics such as creating Google alerts, searching for PDF files, the online availability of Minnesota highway maps and the use of social networking platforms. *New Library Materials* replaces and improves upon *Recent Acquisitions*, which had been published bimonthly.

Finally, the Library continued to update its collections with new book and journal titles, including two important journals: *Leader to Leader* and *Bridge Structures: Assessment, Design and Construction*.

All of these services are critical to alerting engineers to new resources in their fields, helping to ensure that the most recent information will be taken into account when setting Department research priorities and performing research.

Outreach and Recognition

To ensure maximum use of its resources, the Library has continued its commitment to outreach—both to internal and external stakeholders. This year, the Library reached out to 500 Minnesota city and county engineers, informing them of its services and adding them to its *New Library Materials* distribution list. It also began sending all new Mn/DOT employees a personalized letter informing them of library services and offering them a tour. A follow-up letter introduces the periodical routing services.

Because the Library is an important resource to the general population, its public profile is an ongoing priority. In June, an article at *MinnPost.com* entitled "Who Knew? Mn/DOT Library is little-known gem," described the Library's unique role as a critical source for information often not available anywhere else in Minnesota and sometimes in the world.

Also this year, the Library Web site was featured for its excellence in providing access to the best transportation resources available electronically during an internationally broadcast webinar about transportation information resources. The Library Web site includes integrated access to electronic journals and databases, is frequently updated with new materials and is checked to ensure its links are accurate.

A Critical Investment in Continued Excellence

Established in 1957, the Library is internationally acclaimed for its expert staff, which collectively has 59 years of experience. It is also well-known for its historic, fully catalogued and easily accessible collection of transportation planning and civil engineering materials.

But far from being simply caretakers of a physical collection, Mn/DOT librarians are information experts skilled at quickly navigating the ever-expanding thicket of electronic databases to find the right resource for a

given problem. That expertise helps reduce duplication of effort and can save Mn/DOT a significant amount of money by saving engineers time. Senior engineer John Siekmeier, for instance, was able to eliminate the need for years of laboratory analysis during a MnPAVE project after librarians provided him with critical reports, saving Mn/DOT hundreds of thousands of dollars and speeding up the development of MnPAVE design software by several years. "This was not an isolated case," noted Siekmeier. "The Library has repeatedly tracked down reports for us that have prevented us from replicating previous work."

These sentiments are shared by Mn/DOT staff generally. In various user studies performed by the Library to help improve its performance, many users have commented on the consistent and timely delivery of services and the value added to their work.



The transportation sector depends on the wide dissemination and application of new technologies and research findings for its continued growth, and the Library continues to play a critical role in this dissemination. As 2009 nears, Library staff members are focused on future planning to continue this mission. This year, the Library created a dedicated area for access to documents related to the I-35W bridge collapse.

Research Services and LRRB Partnerships and Programs

Research Services maintains partnerships with Mn/DOT offices and staff as well as with academia, industry, federal and local government agencies, other state transportation agencies, AASHTO and TRB. Regular communication with our partners keeps us abreast of both the critical issues facing transportation practitioners and the solutions already under development across the country. This awareness helps us develop research priorities for the department and deliver high-quality research results and implementation products while ensuring that our efforts complement federal, state and local programs.

Mn/DOT Internal Partnerships

Research Services solicits innovation needs statements from other Mn/DOT offices and districts. Then we work with the office to develop a project that will assist in solving the problem. We also look at the needs of other offices that may be affected by the project. Mn/DOT's current offices and districts are:

Mn/DOT Districts

- District 1: Duluth
- District 2: Bemidji
- District 3: Brainerd
- District 4: Detroit Lakes

Mn/DOT Offices

- Administration
- Aeronautics
- Affirmative Action
- Bridge
- Civil Rights
- Construction & Innovative Contracting
- Decision Support
- Electronic Communications
- Environmental Services
- External Partnering
- Freight & Commercial Vehicle Operations

- Metro District
- District 6: Rochester
- District 7: Mankato
- District 8: Willmar
- Human Resources
- Investment Management & Performance Measures
- Land Management
- Maintenance
- Materials
 - Project Scope & Cost Management
- State Aid for Local Transportation
- Technical Support
- Traffic, Safety and Technology
- Transit
- Transportation Data & Analysis

A few Mn/DOT offices have research programs of their own. Research Services works in various ways to support these programs, described below.

Minnesota Road Research— Office of Materials

Minnesota Road Research is Minnesota's Local and National Research and Technology Center. Located near Albertville, Minn., the facility is an outdoor cold-region pavement testing laboratory consisting of 6 miles of pavement sections with embedded electronic sensors. Researchers around the world use the MnROAD facilities and data. http://www.dot.state.mn.us/mnroad/index.html

Minnesota Guidestar— Office of Traffic, Safety and Technology

Minnesota Guidestar performs a broad range of Intelligent Transportation Systems activities to assist in advancing ITS technology and programs to help achieve statewide and local transportation objectives. Its success is attributed to the strong partnerships developed with the public sector, the private sector and academia.

http://www.dot.state.mn.us/guidestar/

Maintenance Operations Research— Office of Maintenance

Mn/DOT's Maintenance Operations Research Section has an active, applied "on-the-road" research program. Its purpose is to promote innovations in Mn/DOT operations and maintenance by stimulating and conducting research in the areas of winter maintenance, road and bridge maintenance, building maintenance, operations management, roadside maintenance, general maintenance, work zone safety and technology transfer. While "on the road" research is its focus, the program will support laboratory research. http://www.dot.state.mn.us/maint/research.html

Mn/DOT External Academic Partnerships University of Minnesota, Five Campuses (Twin Cities, Crookston, Duluth, Morris and Rochester)

The University of Minnesota Twin Cities campus is among the largest research universities in the country and is the largest transportation research facility in Minnesota. The Center for Transportation Studies, located on the Twin Cities campus, addresses the need for closer cooperation between university faculty and state and federal departments of transportation. CTS also strengthens the university's role in transportation research, outreach and education.

http://www1.umn.edu/twincities/index.php Research Services has a strong partnership with CTS.

This partnership has been ongoing since the center's inception in 1987. The mission of the partnership is to bring together Minnesota's primary transportation agency and its major research and education university to advance transportation knowledge and foster innovations that improve Minnesota's transportation systems and services. http://www.cts.umn.edu/

The Duluth Campus houses the Northland Advanced Transportation Systems Research Laboratory. In March 2001, the Northland Advanced Transportation Systems Research Laboratory was established as an advanced research program to develop innovative technologies for safe, productive and sustainable transportation systems in northern areas.

http://www.d.umn.edu/natsrl/

Minnesota State Colleges and Universities— 37 Public Institutions

http://www.mnscu.edu/

The Mankato campus recently created the Minnesota Center for Transportation Research and Implementation. The center addresses the needs of Minnesota and the nation by bridging the gap between research and practice in the critical areas of transportation construction and materials. http://www.mnscu.edu/campuses/profiles/msumankato. html

Other University Partners

- Iowa State University
- · Michigan State University
- Michigan Technological University
- Pennsylvania State University
- · University of Illinois
- University of North Dakota
- University of Northern Iowa
- University of Wisconsin—Madison

Other Mn/DOT External Partnerships

The LRRB supports the local Operational Research Assistance Program effort and Minnesota LTAP.

Operational Research Assistance Program

The Operational Research Assistance Program aims to promote innovations in operations and maintenance methods, materials and equipment for a safer, more efficient and environmentally sound statewide transportation system. http://www.cts.umn.edu/Research/ProjectDetail. html?id=2008034

Minnesota LTAP

Minnesota LTAP is part of the national LTAP formed in 1982 by the FHWA to provide local agencies with information and training programs that address the maintenance of local roadways and bridges. The Tribal Technical Assistance Program was formed in 1991. Minnesota's LTAP, administered by CTS, conducts workshops and seminars, conferences, customized training, demonstrations and distance learning. In addition, Minnesota LTAP publishes newsletters and maintains a Web site with extensive resources.

http://www.mnltap.umn.edu/

Transportation Engineering and Road Research Alliance

Transportation Engineering and Road Research Alliance is a research governance structure formed in 2004 to foster a comprehensive road research program. TERRA brings together government, industry and academia in a dynamic partnership to advance innovations in road engineering and construction. TERRA's partnering efforts reach beyond Minnesota to include transportation organizations in other states and in Europe. One of TERRA's main focus areas is to expand utilization of the MnROAD test facility. http://www.terraroadalliance.org/

AASHTO Research Advisory Committee

The concept of the Research Advisory Committee was developed during a meeting of the Task Force on AASHTO Organization in the summer of 1987. Shortly following the meeting, AASHTO established Standing Committee on Research and its Research Advisory Committee. RAC members, among other duties, provide advice about transportation research matters, rate each year's problem statements for the National Cooperative Highway Research Program and share state-sponsored research to avoid duplication. The Research Services director is Mn/DOT's representative on RAC.

http://cms.transportation.org/?siteid=55&pageid=863

FHWA—Turner-Fairbank Highway Research Center

The Turner-Fairbank Highway Research Center is a federally owned and operated research facility in McLean, Va. TFHRC is the home of FHWA's Office of Research, Development and Technology. TFHRC provides FHWA and the world highway community with the most advanced research and development related to new highway technologies. The research focuses on providing solutions to complex technical problems through the development of more economical, environmentally sensitive designs; more efficient, quality-controlled construction practices; and more durable materials. The end result is a safer, more reliable highway transportation system. http://www.tfhrc.gov/about.htm

FHWA Minnesota Division Research and Technology Center

The Minnesota Division is responsible for overseeing the Federal State Planning and Research Program and LTAP in our state.

http://www.fhwa.dot.gov/mndiv/programs/research.htm

FHWA Transportation Pooled Fund Program

The Transportation Pooled Fund Program, sponsored by FHWA, TRB and AASHTO, allows federal, state and local agencies and other organizations to combine resources to support transportation research studies. The TPF Program has been in operation for more than 20 years, with nearly 200 projects currently active, valued at more than \$130 million of pooled investment. Mn/DOT makes good use of this program to pursue joint research on subjects of interest to other states and FHWA. http://www.pooledfund.org/

TRB

TRB is a division of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance. The mission of TRB is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary and multimodal.

TRB also administers a number of major research programs sponsored by other organizations, including NCHRP. http://www.trb.org/

NCHRP

NCHRP is sponsored by the member departments (individual state departments of transportation) of AASHTO, in cooperation with FHWA. NCHRP was created in 1962 as a means to conduct research in acute problem areas that affect highway planning, design, construction, operation and maintenance nationwide.

http://www.trb.org/CRP/NCHRP/NCHRP.asp

About LRRB

LRRB MISSION

The mission of the LRRB is to serve local road transportation practitioners through the development of new initiatives, the acquisition and application of new knowledge, and the exploration and implementation of new technologies.

MAKING A DIFFERENCE

The LRRB has helped local communities offer rural safety workshops, update crash analysis software, explore the environmental benefits of porous pavements, and evaluate the performance of storm water treatment technology. Currently, the LRRB is supporting a pavement preservation project, investigating methods to extend the service life of pavement to as much as 60 years.

GRASSROOTS INVOLVEMENT

The transportation practitioners who are responsible for county highways and city streets best understand the problems and challenges in providing safe, efficient roadways. The LRRB enables them to participate in setting the research agenda.

Established through Minnesota state legislation in 1959, the Local Road Research Board brings the latest developments in transportation research to the state's city and county engineers. Research applications range from new and more economical ways to recycle pavement to better inspection techniques for bridges.

The LRRB is funded from the county state-aid highway fund and the municipal state-aid street fund, with the funding amount set at 0.5 percent of this state aid allocation. The LRRB in turn funds basic and applied research conducted in close partnership with the University of Minnesota, other regional universities, the Minnesota Department of Transportation personnel, and other consultants and organizations.

The 10-member board includes city and county engineers, the State Aid Engineer, the director of the Mn/DOT Office of Materials, a University of Minnesota Center for Transportation Studies representative and the director of Mn/DOT Research Services.

The Research Implementation Committee (http:// www.lrrb.org/ric.aspx) is a subgroup of the LRRB. The goal of RIC is to make information available and transfer research results into practical application.

The LRRB approves and funds the best innovative research that responds to ideas submitted by local transportation practitioners. Investigators from Mn/ DOT, regional universities and consulting firms then conduct the selected research. The LRRB monitors the progress of this research, and Mn/DOT provides contract administration services, technical assistance and other administrative support.

Strategic Goals

The LRRB is focused on research projects that improve Minnesota's local government road system with regard to:

- 1. **Design**—the determination of the need for and nature of a proposed road system project
- 2. **Construction**—the implementation of the plans and specifications from the road system design process
- 3. **Maintenance/Operations**—the operation and maintenance of the road system investment
- 4. Environmental Compatibility—the integration of the local road system into the community to minimize adverse environmental impacts while contributing to economic and social well-being



Partial-depth repair, a pavement rehabilitation procedure used when deterioration does not extend to the full depth of the pavement, is one of the procedures covered by the new **State Aid Concrete** Best Practices Manual, recently produced by the LRRB. This concise, definitive handbook provides guidance for city and county engineers to select the most cost-effective ways to repair their roads, sidewalks, medians, curbs/ gutters, and more.

Research Highlights

Recent LRRB-sponsored research includes many successful projects designed to help improve the quality of Minnesota's transportation systems.

In 2006, LRRB's Research Implementation Committee partnered with Iowa State University's Center for Transportation Research and Education to develop a powerful and easy-to-use Crash Mapping and Analysis Tool that engineers can use to identify problematic road locations and traffic control needs, assess how local construction and maintenance affect safety, and generate crash statistics for use in funding requests. LRRB also recently supported an effort to update the *State Aid Concrete Pavement Rehabilitation Best Practices Manual* (see inset), which provides specifications for repair of city and county concrete pavements in Minnesota.

LRRB has also seen positive results from its 2008 implementation effort on intelligent compaction, a process that makes use of the latest technologies for creating uniform, stable road foundations more efficiently and at lower cost. Currently, LRRB is supporting a pavement preservation project investigating methods to extend the service life of pavement to as much as 60 years.

The Technical Summaries that follow describe these and other LRRB research projects—the research needs, goals of investigators, how they carried out the projects and what they learned.

2008 Research Reports and Implementation Products

The LRRB is pleased to have published the following products in 2008. For bolded items, a two-page Technical Summary appears on the following pages, in the order presented here:

2008-02	INV 838: Evaluation of Paving Fabrics for Isolation of Bituminous Cracking		
2008-03	INV 827: Investigation of Winter Pavement Tenting		
2008-06	INV 808: Pavement Rehabilitation Selection		
2008-08	Development of Improved Test Rolling Methods for Roadway Embankmen	nt Construction	
2008-16	INV 817: Determination of Optimum Time for the Application of Surface Treatments to Asphalt Concrete Pavements - Phase II		
2008-20	Best Practices Handbook for Roadside Vegetation Management		
2008-23	INV 857: Effects of Seasonal Changes on Ride Quality at MnROAD		
2008-24	INV 839: Toolbox to Evaluate the Impacts of Roundabouts on a Corridor or	Roadway Network	
2008-25	Warrants for Right-Turn Lanes/Treatments on Two-Lane Roads		
2008-28	INV 836: Design Procedure for Bituminous Stabilized Road Surfaces for		
	Low Volume Roads	£	
2008-32	INV 823: The Road to a Thoughtful Street Tree Master Plan	A	
2008-35	INV 833: Design Tool for Controlling Runoff and Sediment from High-		
	way Construction		
2008-42	INV 849: Study of Environmental Effects of De-Icing Salt on Water Qual-		
	ity in the Twin Cities Metropolitan Area, Minnesota		
2008-50	INV 841: Long Term Maintenance Effects on HMA Pavements Caused by Rumble		
	Strips and Available Preventive Treatment Methods		
2008-54	INV 822: Crack Sealing and Filling Performance		
2008RIC03	Rural Road Safety Solutions Workshop Materials		
2008RIC04	Training Module for Pavement Rehabilitation Selection	Recognizing that local transportation	
2008RIC06	Resource for Implementing a Street Sweeping Best Practice	agencies have	
2008RIC08	Bridge Management Tool Phase I	limited budgets and that rural roads	
MnPAVE08	INV 828: Local Road Material Properties and Calibration of MnPAVE	require a different	
TRS0801	Transportation Research Synthesis - Traffic Calming for High-Speed Rural Roadway:	(INV881) approach than Mn/	

This list can be found with added details and alternate sorting in the *Mn/DOT Research Services At-A-Glance* document that accompanies this report. The *At-A-Glance* document also includes a full list of LRRB-sponsored projects currently in progress.

In addition, we have provided in the Technical Summaries that follow an interim summary (IMPL-LWDTS) on a final report that has not yet been issued: Project 2006-096P, "Using the Dynamic Cone Penetrometer (DCP) and Light Weight Deflectometer (LWD) for Construction Quality Assurance."

For more information about any of these projects, search for reports and initiate queries at http://www. lrrb.org/. Our Web site lists LRRB members, provides news and events information, explains more about our mission and plans, and provides links to useful Web-based tools like the Geosynthetic Design Guide, Minnesota Research Test Section Tracking database and Mix Asphalt Design Tool. Recognizing that local transportation agencies have limited budgets and that rural roads require a different approach than Mn/ DOT's large trunk highways, the LRRB has funded research and implementation projects to support cost-effective construction and maintenance of lowvolume roads.



TECHNICAL SUMMARY

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Principal Investigator: Courtney Kleven, Red Lake County

PROJECT COST: \$30,000



A contractor lays spun-glass paving fabric over asphalt before overlay.



Evaluation of Paving Fabrics for Isolation of Bituminous Cracking

What Was the Need?

Because of increasing traffic levels and weights on county state-aid highways, thousands of miles of Minnesota pavement will need to be upgraded in coming years from their current 7-ton capacity to 9- and 10-ton capacities. These highways already require seasonal maintenance to repair thermal and stress cracking: fissures that mar the surface because of freeze-thaw conditions and heavy truck traffic.

To mitigate the impact of these cracks, crews typically mill off several inches of the pavement surface before performing a maintenance overlay, reconstruction or structural upgrade. Milling is intended to isolate the cracks to prevent them from reflecting up through the overlay into the new asphalt surface.

Milling is expensive, as is reconstructing the highway afterward. Pavement fabrics may offer the potential to isolate cracks at a much lower cost, and fabric producers make dramatic claims that their products will extend the performance of rehabilitated pavements. By laying down spun-glass fiber fabrics over damaged pavement, then laying new asphalt over them, the upgraded asphalt pavements may reduce reflection of old cracks into new surfaces.

What Was Our Goal?

This study was initiated to learn if spun-glass fiber fabrics could be effective in:

- Isolating new overlays from cracks and sealants in old pavement, and preventing moisture intrusion.
- Increasing the ability to utilize existing base and pavement layers when upgrading a pavement to higher load-carrying capacity.
- Reducing reflection of old cracks into the upgraded pavement surfaces.

What Did We Do?

The Red Lake County Engineer and his staff studied the impacts of spun-glass paving fabrics in pavement sections in Red Lake County, with similar weather conditions for all sections. The tested pavements were scheduled for structural overlays to bring their capacity to 10 tons.

Crews prepared pavement sections in 300-foot segments. The first and third were milled and overlaid, or were simply given a 0.5-inch leveling course before overlay, and the middle segment was covered with fabric and overlaid. The sections included 11 that used the three-part pavement configuration; one section with a segment of fabric and another without; and two other sections with fabric laid only at the centerline. Specific steps included:

- A video survey documenting the pavement section's condition before upgrade.
- Documentation of procedures and materials used in the installation of fabrics and overlays. Many segments employed leveling courses of asphalt, in which material is laid thinly and leveled with a paver blade before overlay with fabric.
- Evaluation with video of pre- and post-installation surface conditions.
- Testing of sections for strength and cost comparisons to mill-and-replace control sections.
- Monitoring of reflective cracking of fabric and control sections over a three-year period.

"Spun-glass paving fabrics did not appear to significantly retard transverse and longitudinal cracks. Historically, paving fabrics have not performed very well in this environment. I do not think there will ever be a fabric effective for this kind of application."

-Lou Tasa,

Mn/DOT District State Aid Engineer

"Until better data on fabrics is demonstrated, blade laid leveling courses and overlays would be my recommendation for both maintenance and structural overlays."

-Courtney Kleven, Highway Engineer, Red Lake County

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Minnesota Department of Transportation Research Services Section MS 330, First Floor 395 John Ireland Blvd. St. Paul, MN 55155-1899 (651) 366-3780 www.research.dot.state.mn.us



After applying a 0.5-inch blade asphalt leveling course, contractors laid paving fabric and overlaid it as in the left lane shown above. The fabric demonstrated no real benefit over sections without fabric.

Investigators evaluated spun-glass paving fabrics in terms of how well they worked with current overlay paving procedures, how well they isolated existing damage from new overlays during installation, how well they reduced propagation of cracks and joints into the new overlays, and how they compared in cost to mill-and-replacement overlays.

What Did We Learn?

According to our evaluation criteria, the fabric performed poorly, countering the claims of pavement fabric vendors. While spun-glass paving fabric can isolate heavy crack sealant from new overlays at less expense than milling and replacing asphalt with sealant, the use of paving fabric between asphalt layers added no structural strength and failed to retard early thermal and centerline cracking. Fabric sections and control sections with no fabric performed equally in terms of distress cracking. This cracking did not reflect through overlays in the first two years following installation. Investigators concurrently examined the impact of subjecting pavement sections to a 0.5-inch leveling course before overlay instead of milling them. They found that this practice also mitigates heavy crack sealant effects on main courses.

Costs can be compared as follows (using 2005 prices):

- 0.5-inch blade laid leveling course: \$0.77/square yard.
- Spun-glass paving fabric: \$2.50/square yard.
- Milling and replacing 2 inches of asphalt: \$3.43/square yard (\$0.60 to mill, \$2.83 to replace).

The investigator has recommended the use of blade and overlay methods for maintenance and structural upgrade until compelling data is presented that fabrics prevent propagation of damage into overlays.

What's Next?

The project panel has recommended monitoring the test sections at five and 10 years post-installation as reflective cracking develops. The investigator has also recommended a similar evaluation of paving fabric in less severe winter conditions.

The Minnesota DOT State Aid Division will be apprised of the results of this research. Mn/DOT and LRRB will continue to sponsor research into methods and materials to mitigate reflective cracking, and are also very interested in innovations in preoverlay surface preparation.

This Technical Summary pertains to the LRRB-produced Report 2008-02, "Evaluation of Paving Fabrics for Isolation of Bituminous Cracking," published January 2008. The full report can be accessed at http://www.lrrb.org/PDF/200802.pdf.



TECHNICAL SUMMARY

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Principal Investigator: Eddie Johnson, Mn/DOT eddie.johnson@dot.state.mn.us

PROJECT COST:

\$25,126





String lines (top) and thermal imagery (bottom) were used to measure pavement tenting.



Investigation of Winter Pavement Tenting

What Was the Need?

Pavements sometimes respond to freezing temperatures by heaving at existing joints and cracks. Pavement tenting occurs when this heaving lifts up the pavement on both sides of a joint or crack, creating a ridge or peak along the joint. Found in transverse cracks in asphalt, pavement tenting, if severe, can have a significant effect on the quality of driving experience.

Previous research suggests that road deicing chemicals may contribute to tenting. More research was needed to verify these findings and to establish what Minnesota municipal, county and state engineers believed to be:

- The prevalence and severity of tenting in their road networks
- The most important factors contributing to tenting
- Pavement structures that are tent-resistant or tent-susceptible

What Was Our Goal?

This research sought to identify the causes of winter pavement tenting to test the theory that deicing chemicals, sands and crack sealing influence tenting. Researchers also sought to recommend pavement design and maintenance strategies for preventing tenting from recurring in roadways previously affected by it.

What Did We Do?

Researchers first conducted a literature search into current theories for winter tenting and methods used for measuring and analyzing it. They then surveyed municipal, county and state engineers regarding the frequency of winter tenting in their areas, factors the engineers believed influenced tenting, and remedies typically used to treat it.

Finally, investigators performed inspections and cold weather monitoring at 11 sites for two years to test factors that survey comments identified as most important to winter tenting: surface types, maintenance treatments and base materials. Investigators periodically collected data at these sites, making manual straight-edge measurements, gathering and performing laboratory conductivity tests on samples taken from road surfaces and transverse cracks, using thermal imaging and string lines, and recording temperatures. They also conducted forensic studies at two of these sites by using excavation pits to sample base materials for conductivity and gradation analysis, as well as by performing longitudinal profile analyses on these pits. The resulting data was used to examine relationships between winter tenting severity, temperature conditions, the presence of deicing chemicals, and the effect of maintenance activities and road treatments.

What Did We Learn?

Almost 40 percent of survey respondents reported tenting in their local road systems, typically covering about 25 percent of a system, with about 25 percent of this coverage characterized as severe. Tenting affects ride quality, particularly before the spring thaw, and has been linked to the intrusion of winter maintenance materials into the base. Sealing cracks consequently reduces tenting; field measurements showed that the concentration of deicing salts decreased with depth and distance from cracks. The literature suggested that high amounts of recycled asphalt pavement in base layers may also contribute to tenting. The study results show that tenting occurs in both virgin aggregates and recycled base materials, including base containing recycled concrete.

"Places with open, transverse cracks that experience regular deicing are susceptible to pavement tenting. Additionally, roads that experience winter heaving and the typical subsequent associated pavement distresses may eventually experience cracking and tenting."

-Tom Struve,

Superintendent of Streets, Equipment and Central Services, City of Eagan

"Our field measurements show that crack sealing was an effective treatment for tented roads. I believe sealing should be done as early as possible to reduce accumulation of distress."

-Eddie Johnson,

Research Project Engineer, Mn/DOT Materials and Road Research

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To measure the vertical heaving effect of tenting on transverse cracks, investigators used a steel level near the crack. This process involved either measuring the tenting projected to a location 1 foot from the crack or measuring the cupping at the crack.

Investigator recommendations for combating pavement tenting include:

- Seal cracks as early as possible. This was shown to reduce the height of tenting, cutting surface roughness by 20 percent to 35 percent during the following year.
- Use the most elastic and durable sealant available on roads with wide cracks that are prone to tenting. Longitudinal profile measurements showed that heaving may occur several feet from crack openings.
- Inspect sealants in cold weather to identify adhesion failures, which may not show in warm weather.
- For pavements prone to tenting, evaluate moisture sensitivity and salt contamination of the base and consider the results when selecting future pavement rehabilitation or maintenance strategies.
- In cases of contaminated bases or moisture-sensitive structures, consider full-depth reclamation and base replacement.

Investigators did not recommend any changes in pavement design, in part because all evaluated base types showed tenting.

What's Next?

This study is one of the first addressing winter pavement tenting; treatment of tenting remains a work in progress. Mn/DOT will continue to monitor selected pavement sections and will communicate with counties as they continue to develop and refine plans to address pavement tenting. More testing may be useful in identifying ways to treat the factors that contribute to pavement tenting.

Treatment of severely tented pavements requires further investigation, particularly for pavements otherwise in good condition. The impact of weather on areas with contaminated bases should also be investigated, as it is not clear what role falling temperatures play in tenting, particularly in areas with bases contaminated by salt and water incursion.

This Technical Summary pertains to the LRRB-produced Report 2008-03, "Investigation of Winter Pavement Tenting," published January 2008. The full report can be accessed at http://www.lrrb.org/PDF/200803.pdf.



TECHNICAL SUMMARY

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Principal Investigators: Joe Labuz, University of Minnesota Shongtao Dai, Mn/DOT

> PROJECT COST: \$102,000



Transverse cracks like these may be repaired by full depth reclamation or cold-in-place recycling, but are too severe for mill and overlay.



Decision Tree for Choosing the Optimal Asphalt Pavement Rehabilitation Method

What Was the Need?

In recent years, Minnesota engineers have increasingly relied on recycling techniques when repairing the state's asphalt roads. In addition to the savings from reused materials, recycling can save money in hauling and processing costs. Moreover, rehabilitation through recycling can result in shorter construction time when compared to total reconstruction.

Minnesota roads have already benefited from the following rehabilitation processes, which were central to this study:

- Full Depth Reclamation. The entire paved surface is reclaimed, pulverized and recycled into a usable base. The material may be strengthened further with stabilizing agents. This is the best of the three methods for eliminating road distress, but it is also the most labor-intensive.
- **Cold-In-Place Recycling.** The top 2 inches to 4 inches of pavement are reclaimed and cold-mixed with new asphalt concrete. The recycled material is applied on top of 1 inch of original hot-mix asphalt. This method is more suitable for low-volume roads than high-volume roads.
- Mill and Overlay. The top 1 inch or 2 inches of pavement are milled (removed), and a new layer of HMA is applied. This method is relatively quick and inexpensive, but the roads tend to have shorter life expectancy.

While Mn/DOT had funded several prior research efforts concerning these techniques, before this study, no formal guidelines had been established for Minnesota engineers to follow when deciding which technique to use or which specifications to follow for a given project. Often decisions were made based on personal experience and a degree of experimentation.

What Was Our Goal?

The primary objective of this effort was to produce a best practices guide to recommend pavement rehabilitation methods for asphalt pavements based on current, available pavement performance data. This guide would also provide construction specifications for each of the three rehabilitation techniques.

What Did We Do?

Researchers began by gathering data from available asphalt pavement rehabilitation projects throughout Minnesota from the past 20 years, including some current projects for which on-site visits were possible. For each project, the database describes the road conditions before and after rehabilitation, focusing on several parameters: cracking, ride, rutting, age and traffic volume. From this data, researchers were then able to calculate (for each road):

- Ride quality index (indicating pavement roughness).
- Surface rating (indicating overall pavement distress).
- **Individual weighted distresses** (indicating pavement distress for a specific type of cracking).

"We developed a database of asphalt road rehabilitation projects that will also prove valuable for future studies."

-Brad C. Wentz, Becker County Highway Engineer

"The study provides an excellent tool for county and city engineers to use when deciding which type of rehabilitation techniques to implement."

-Shongtao Dai, MnROAD Research Operations Engineer

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This cold-in-place recycling train is used for reclaiming the surface, conveying and crushing the millings, mixing the recycled material and laying the new cold mix.

They then analyzed the data and consulted highway engineers from six districts around Minnesota to create a decision tree for determining the most suitable method of rehabilitation for a given project. In addition, they also developed a list of best practices for each of the three methods.

What Did We Learn?

Decision Tree. Researchers were able to set a surface rating threshold at which rehabilitation becomes necessary. When the SR is greater than 3.0 (on a scale of 4.0), repairs may be avoidable, but when the SR is lower than 3.0, one of the three rehabilitation methods is recommended. The project report provides a guide for calculating the necessary values for the decision tree. Factors considered in the decision include road geometrics, pavement condition and bridge deck structural adequacy. The report includes a step-by-step checklist to provide engineers with a simple and useful tool for following the recommended decision procedures.

Best Practices. Once the decision tree is executed, the engineer can refer to best practices guidelines produced by this study for implementing the rehabilitation project. Depending on the method chosen, the report provides design and construction specifications covering necessary pavement thickness, ideal mixture design, equipment requirements and other factors. These guidelines may require field adjustments, but they provide a starting point for implementing the rehabilitation methods.

What's Next?

The results of this effort are being incorporated into a pavement rehabilitation training course for county and city engineers to be administered through the Minnesota Local Technical Assistance Program.

This study highlights the value of a comprehensive database for road rehabilitation projects. The primary investigators suggest that this database should be maintained and expanded going forward. Such a database will prove valuable for future studies.

Also, this project focused on the effectiveness of the three rehabilitation techniques, but only generally treated economic considerations. While the appropriate choice of rehabilitation method will likely lead to cost savings, a new study examining the cost considerations and life-cycle costs of each method is a logical next step.

This Technical Summary pertains to the LRRB-produced report 2008-06, "Pavement Rehabilitation Selection," published January 2008. The full report can be accessed at http://www.lrrb.org/PDF/200806.pdf.



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Principal Investigators:

Andrew Drescher, University of Minnesota James Hambleton, University of Minnesota

PROJECT COST: \$110,000



Current test rolling equipment is cumbersome and unsuitable for testing lifts less than 30 inches thick.



Developing Improved Test Rolling Methods for Roadway Embankment Construction

What Was the Need?

Before pavement construction, crews test roll the soil that will act as the pavement subgrade by towing a two-wheeled vehicle of known weight over the soil and measuring the depth to which its wheels penetrate the soil. If this depth exceeds a Mn/DOTspecified limit, the subgrade must be further compacted before it is considered acceptable for placing the road's aggregate base.

The weight of Mn/DOT's current test rollers makes them impossible to use for projects that are not intended to support very heavy loads, and they use wheels that are no longer manufactured. The current test rolling procedure is also very time- and labor-intensive, and involves safety risks: One or two inspectors must walk alongside roller tires, which are prone to exploding.

To best redesign this system, Mn/DOT had to address limitations of the current test. Test rolling measurements using flexible pneumatic tires can vary due to coupled deformation of the wheel and soil. Crews often infer wheel penetration by measuring the distance between the wheel axle and the soil level surface, but this measurement can be misleading because of the effect of tire flexibility.

Moreover, there was no available means to relate test roller wheel penetration to basic soil mechanical properties. Without a theory linking sinkage to soil properties and acceptable mechanistic parameters, test rolling remains a visual, empirical tool rather than a quantitative way to obtain material characterizations for use in mechanistic design.

What Was Our Goal?

The objective of this project was to better understand the deformation of soils and tires in test rolling as well as the relationship between test roller measurements and soil strength properties in order to recommend improvements in test rolling equipment and procedures.

Investigators aimed to formulate a theoretical model for roller wheel penetration and then validate this model via experiments in which the various parameters influencing test rolling results—including test roller weight, wheel type and size, soil mechanical properties and soil layering—were well-controlled.

What Did We Do?

Investigators first evaluated existing research on processes involving soil-wheel interaction, as well as current test rolling specifications. Then they developed theoretical models for soil-wheel interaction. This modeling consisted of both comprehensive, threedimensional numerical simulation and an analytical method that provided mathematical expressions relating wheel weight, size and flexibility to soil properties and sinkage.

The next step was to apply the theories developed during the modeling phase by evaluating the effects of test rolling variables such as wheel weight and size, soil layer depth and strength, and soil type on roller penetration. Investigators compared theoretical predictions of soil mechanical properties determined from laboratory testing to the results of field and lab-scaled rolling and indentation tests. "For a host of reasons, the old test roller system was no longer sustainable. This study served to better define the soil mechanics related to the new system we are building."

-John Siekmeier,

Mn/DOT Senior Research Engineer

"Test rolling has great potential as a tool for characterizing in situ subgrade strength over a broad area. Though test rolling in current practice is somewhat crude, the relationship between rolling wheel penetration and material strength parameters is quantifiable."

-James Hambleton, University of Minnesota Department of Civil Engineering

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Evaluating test-rolled soil using current test rolling procedures: passing inspection (left), near failing (center) and failing (right).

What Did We Learn?

This study established relationships between sinkage in cohesive and granular soils and the variables most important to test rolling, including wheel weight and geometry, wheel type, and soil layering. Test rolling proved more sensitive to weak soil layers underneath the tested layers than to strong layers beneath.

Poor conditions at selected sites prevented effective field evaluations. However, scaled lab tests of rigid and flexible wheels on cohesive and granular soils verified the theoretical models and showed that test rolling results can be predicted from soil properties. The study showed that sinkage and rut depth from rolling can be used to determine soil properties.

This study produced several recommendations helpful to designing a new test roller system:

- Use rigid rather than flexible wheels, and offset test roller wheels from driving wheels.
- Use two or more offset wheels with different weights or geometries to measure both friction angle and cohesion of a soil.
- When rolling soils display a uniform strength (such as clean sand or moist clay), use single wheel types to determine friction angle or cohesion, but for mixed soils, use two wheels of different sizes or carrying different weights.
- Reduce the test roller weight by half (without changing wheel geometry) to reduce the sinkage by roughly one-half in granular soils and one-fourth in cohesive soils.

What's Next?

This study demonstrated that test rolling can effectively determine subgrade strength during construction. Validation of the accuracy of this study's theoretical models will require field testing at multiple sites over various representative subgrade materials.

A \$253,000 implementation effort by investigators at Minnesota State University, Mankato, is under way to develop a new automated test roller system that is more mobile and adaptable to a wide variety of projects. This new system will include specifications that account for variations in projects such as the thickness and type of subgrade materials.

This Technical Summary pertains to the LRRB-produced Report 2008-08, "Development of Improved Test Rolling Methods for Roadway Embankment Construction," published February 2008. The full report can be accessed at http://www.lrrb.org/PDF/200808.pdf.



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Principal Investigators:

John D. Krenz, Minnesota State University Ann Johnson, Professional Engineering Services Ltd.

IMPLEMENTATION PROJECT COST:

\$52,500



Woody vegetation in roadsides provides cover for deer and increases the risk of deer-vehicle collisions.



Putting Research into Practice: Best Practices Handbook for Roadside Vegetation Management 2008

What Was the Need?

Managing vegetation is a critical factor in roadside maintenance, which is an important priority at all levels of Minnesota government. A healthy roadside environment reduces maintenance needs and costs, improves water quality, provides habitat for wildlife populations and maximizes safety for travelers. In 2000, the Minnesota Local Road Research Board published the <u>Best Practices Handbook on Roadside Vegetation Management</u>, which identified seven best practices for roadside vegetation management.

This handbook served as a valuable resource to maintenance and engineering staff, and was used widely in Minnesota and other states. However, no printed handbooks remain, and since the handbook's publication, research has led to new findings not covered in the 2000 edition. These findings include information about roadside habitats and their effects on driver safety, as well as techniques for managing deer-car collisions, which are frequent on Minnesota highways.

With driver safety an increasing concern, the handbook's best practices needed to be updated to address the preservation of roadside habitats without compromising driver safety. This need became especially urgent in light of the 2005 Mowing Law, which required road authorities to reduce mowing and encouraged growth of native plant communities to preserve wildlife diversity—practices that can affect roadside safety.

What Was Our Goal?

The objective of this implementation effort was to create standard Mn/DOT guidance, through an update of the handbook, based on the most current research on balancing roadside biological diversity with safety issues caused by vegetation and wildlife.

What Did We Implement?

This project made maximum use of the original handbook; all information from this source that is still accurate is retained in the new edition. Important sources for updates to the new handbook included the following reports:

- "<u>The Effects of Fire Versus Mowing on Prairie Plant Communities</u>" (2003-20), which identifies management processes that benefit a restored prairie and reduce the need for prescribed burning.
- "Deer Avoidance: The Assessment of Real World Enhanced Deer Signage in a Virtual <u>Environment</u>" (2004-13), which identifies signage techniques that reduce the incidence of deer-vehicle collisions on Minnesota highways.
- "Accident Analysis of Significant Crash Rates for Low to Very Low Volume Roadways in 10 Minnesota Counties" (2004-22), which evaluates the causes of vehicle collisions.

How Did We Do It?

Investigators began by conducting a comprehensive review of published scientific literature and unpublished state and local agency reports relevant to roadside management in Midwestern states. They focused on practices to minimize the use of roadsides by wildlife that are hazardous to traffic while promoting the conservation and diversity of those wildlife species that are minimally hazardous to travelers. "The 2000 handbook was a great resource for roadside managers, but we needed a synthesis of new research on the relationship between vegetation, wildlife and driver safety—which the updated handbook provides."

-Paul Walvatne,

Mn/DOT Roadside Vegetation Management Unit Supervisor

"There are lots of valuable wildlife populations that can be cultivated without compromising driver safety. You can judiciously remove woody vegetation to minimize deer collisions and still have very diverse, grass-dominated communities in roadsides."

–John D. Krenz,

Professor, Minnesota State University–Mankato Department of Biological Sciences

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Kestrels are one example of valuable wildlife that can be cultivated without compromising driver safety. Kestrels are often seen hovering while hunting for mice in roadsides.

This research was used to update the seven existing best practices for effective roadside management from the 2000 handbook, and also formed the basis of an eighth best practice detailed in an additional chapter, "Managing Roadside Vegetation for Wildlife & Vehicle Safety."

Once the draft of the updated handbook was complete, a technical advisory panel of industry experts and roadside managers reviewed it for accuracy and clarity. This panel included members of the 2004 Roadside Habitat Advisory Committee and representatives of the Minnesota Department of Natural Resources Roadsides for Wildlife Program, as well as state officials and city and county engineers and natural resources staff.

What Was the Impact?

The new handbook has been widely distributed. The new chapter provides valuable guidance to local officials and Mn/DOT regarding vegetation types (including the safety implications and benefits of using low-maintenance native vegetation in roadsides); species composition; vegetation management (including mowing heights for different types of vegetation); and the frequency and timing of hazardous wildlife road crossings.

The chapter's primary conclusion is that roadside habitats can be managed to balance biological diversity and safety by selectively reducing woody vegetation without entirely removing grass habitats. Woody vegetation such as brush and trees interfere with the line of sight required by drivers to avoid collisions with deer, while grass is important to benign wildlife such as pheasants and ground-nesting mammals.

What's Next?

The updated handbook will be posted on Mn/DOT's Central Office Library Web site for access worldwide. The handbook will also be used by Minnesota's Local Technical Assistance Program in its Circuit Training and Assistance Program courses, and it will be presented at the Spring and Fall 2009 Local Technical Assistance Maintenance expos.

This Technical Summary pertains to the LRRB-produced Report 2008-20, "Best Practices Handbook for Roadside Vegetation Management 2008," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200820.pdf.

The research being implemented via this project can be found mainly in LRRB-produced Reports 2003-20, "The Effects of Fire Versus Mowing on Prairie Plant Communities," published July 2003; 2004-13, "Deer Avoidance: The Assessment of Real World Enhanced Deer Signage in a Virtual Environment," published January 2004; 2004-22, "Accident Analysis of Significant Crash Rates for Low to Very Low Volume Roadways in 10 Minnesota Counties," published March 2004; and the previous version of the handbook, Report 2000-19, "Best Practices Handbook on Roadside Vegetation Management," published September 2000. These reports can be accessed at http://www.lrrb.org/PDF/200320.pdf, http://www.lrrb.org/PDF/200413.pdf, http://www.lrrb.org/PDF/200422.pdf and http://www.lrrb.org/PDF/20019.pdf, respectively.



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Principal Investigator: Lev Khazanovich, University of Minnesota

PROJECT COST: \$79,493



Two-inch lengths of steel reinforcement bar were used as frost pins to measure how far frost heave elevates pavement surfaces.



Effects of Seasonal Changes on Ride Quality at MnROAD

What Was the Need?

During the winter, soil under a roadway that has been saturated with water freezes and expands, causing the road to rise. When this occurs unevenly, the result is rougher roads during the winter and spring, and in some cases, cracked pavement surface layers. This problem of "frost heave" is very common in Minnesota, especially on lower volume roads, and can cause serious damage to concrete, asphalt and gravel pavements. It presents one of the greatest challenges to engineers to keep Minnesota's 130,000 miles of roads well maintained throughout the year. Cracked and heaved pavements lead to a bumpy or otherwise poor driving experience for motorists.

Engineers typically respond to these problems with "rough road" signs in the spring, but in extreme cases, roads may require spot grinding, localized overlays or replacement of pavement and underlying materials. These maintenance responses can be costly. While engineers have reduced the occurrence of frost heave over the last 30 years with more blending of lower-lying materials, little is known about the mechanisms involved.

What Was Our Goal?

The objective of this study was to identify how different pavement designs are affected by frost heave and how this relates to ride quality during different seasons. This information will help engineers design pavements to better withstand seasonal variations.

What Did We Do?

Researchers investigated frost heave by gathering and analyzing related data and correlating it to pavement characteristics and ride quality. Much of this data was from MnROAD test cells constructed in the early 1990s, collected as part of normal operating procedures at the time.

First, they selected 20 pavement sections at the MnROAD research facility—eight constructed with portland cement concrete and 12 with hot-mix asphalt. They then installed frost pins—2-inch-long pieces of rebar—into the pavement sections flush with the surface and surveyed periodically through the seasons to determine the heights of the pins over a four-year period. Mn/DOT's pavement management vans were driven over MnROAD test cells at different times of the year to measure ride quality.

Researchers then evaluated this heave and ride data to determine:

- How different mix designs (HMA, PCC, base types and thicknesses, subgrade type) affect the total (maximum), duration and consistency of frost heave throughout the year
- How the frost measured for the MnROAD test cell designs correlates to the measured ride roughness

What Did We Learn?

Design Features. Investigators found that:

- For concrete, a longer design life has no significant impact on frost heave performance, but design life correlates with better resistance to frost heave in asphalt.
- Clay subgrades experience more frost heave than sand subgrades under both concrete and asphalt.
- Better drainage results in less frost heave for both concrete and asphalt.
- For both concrete and asphalt, thick pavements bear heavier loads and often extend the pavement structure down to the level that frost penetrates the soil, reducing frost heave. A thicker pavement even mitigates the impact of nonuniform frost heave.

"We found essentially that pavements over a sand subgrade, thicker pavement structures and pavements with drainable bases exhibit less frost heave than other pavements."

-Lev Khazanovich,

Principal, Associate Professor, University of Minnesota Department of Civil Engineering

"This study confirmed our current practices in responding to frost heave, but didn't provide enough input to change our design specifications. Improving data collection and ride analysis methods may offer more insight."

-Benjamin Worel, MnROAD Operations Engineer, Mn/DOT Office of Materials

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Damp subgrade and pavement may shift during expansion in freezing temperatures, causing frost heave that can severely damage surface conditions and ride quality.

- Asphalt binder types do not affect frost heave performance.
- In asphalt designs, coarser base materials hold less water and so suffer less frost damage.
- In concrete, joint spacing does not affect overall frost heave magnitude, but frost heave damage is more concentrated in short-spaced slabs, which have smaller areas for the distribution of heave stress.

Ride Quality. While investigators could not confirm a correlation between frost heave and ride quality deterioration on flexible pavements, they did not reject the hypothesis that frost heave degrades ride on rigid pavements insofar as thicker concrete pavements experience less frost heave damage.

Seasonal Variations. Frost pin elevations begin to increase at the end of September and reach their highest points in early March, then decrease until mid-April. From May to September, frost pin elevations change very little. Though ride quality improves in summer months, no seasonal statistical connection was established between pin heights and ride quality.

What's Next?

Investigators suggest that a refined approach to ride quality data collection and assessment methods might offer better data on any correlation between ride quality and frost heave magnitude.

Since thicker MnROAD test cells exhibited less frost heave, which was correlated with ride quality in concrete pavements, there is also a need for further investigation of the benefits of using thicker bases under concrete pavements.

Investigators recommended other improvements in design and construction practices to improve ride quality, including research into the mix design for HMA pavements to reduce thermal cracking—the main cause of roughness—and steps to improve the initial roughness of concrete pavements.



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Principal Investigator: Shauna Hallmark, Iowa State University

PROJECT COST: \$39,444



Roundabouts are becoming increasingly popular for controlling traffic flow at intersections.



Determining the Impacts of Roundabouts on Roadway Networks

What Was the Need?

Roundabouts are gaining popularity in Minnesota as a way to control traffic flow at particular intersections or over roadway corridors. Even though they often resolve identified safety or operational problems at intersections, roundabouts can also negatively affect overall roadway system performance. For example, introducing a roundabout can disrupt planned traffic signal timings and coordination between signals.

When planning an intersection project, highway officials may give little consideration to how roundabouts impact the entire roadway system. Agencies needed a comprehensive resource to help them determine the likely corridor or system impacts of roundabouts for a given highway scenario.

What Was Our Goal?

The main goal of this research was to develop a toolbox to help cities, counties and other agencies evaluate roundabout impacts on urban, rural and transitional intersections, accounting for system continuity, land use and access control scenarios. This project was intended to complement Mn/DOT's <u>Intersection Control Evaluation</u> process.

What Did We Do?

Researchers reviewed existing literature about roundabout performance for various scenarios in the United States. Interviews with officials in jurisdictions with experience in roundabout implementation provided case histories, including insight into seldom-researched scenarios such as roundabouts in a series, impacts to systemwide mobility and access management.

Because sparse data existed on the use of roundabouts in signalized corridors (such as a series of intersections with coordinated traffic signals), two of these were selected for computer modeling. The analysis compared average corridor travel time, delay, stop time and travel speeds to better understand the interaction of signals and roundabouts.

To analyze unbalanced flows, researchers used computer simulations of different traffic scenarios on an intersection modeled after one in Ames, Iowa, analyzing two alternative configurations of the intersection: a traffic signal with left turn lanes and a roundabout.

What Did We Learn?

The completed toolbox provides guidance for:

- The use of roundabouts in both short- and long-term comprehensive planning, for both new and existing roadway networks
- Impacts of roundabouts on corridor mobility and rights of way
- Land-use implications, including school, agricultural and commercial zones
- Impacts of roundabouts on systemwide mobility
- Roundabout performance with unbalanced traffic flows
- Roundabouts and access management
- Impacts on other planning considerations, such as air quality, nonmotorized users, maintaining consistency among neighboring jurisdictions and community character
"This one-of-a-kind resource provides critical guidance for correctly implementing roundabouts on highway corridors."

-Shauna Hallmark,

Transportation Engineer, Center for Transportation Research and Education, Iowa State University

"Transportation providers can avoid unintended problems when roundabouts are considered first from a 'big picture' perspective rather than as isolated, individual intersections."

-Paul Stine,

Mn/DOT State Aid Engineer for Local Transportation

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The toolbox provided data about roundabout effectiveness in a variety of settings. In commercial areas, roundabouts speed up traffic flow, especially during peak travel times.

The project produced models for two scenarios that compared roundabouts to other traffic control alternatives. In one scenario, a corridor was modeled with the existing configuration, addition of left turn lanes and a roundabout. The alternative with left turn lanes performed better in terms of delay than the roundabout alternative. The analysis indicated the use of roundabouts in a corridor with signalized intersections may actually disrupt the smoothness of overall flow along the length of the corridor.

In the second scenario, investigators modeled a roundabout and the left turn lane alternative using unbalanced flows. In this case, the delays at roundabouts were considerably shorter than those at signalized intersections, regardless of whether the volumes were balanced or unbalanced. Both unbalanced and balanced flows showed similar delays and queues. Consequently, roundabouts should not be ruled out as a viable alternative at intersections with unbalanced flows.

What's Next?

Mn/DOT expects this high-value toolkit to be readily accepted and used across the country. The guidelines give local, county and state highway agencies another tool for addressing both short- and long-term safety and operational issues related to roundabouts at intersections. Future "big picture" engineering decisions regarding roundabouts should save money and reduce both crash severity levels and unnecessary delays.

The researchers recommend more study for determining the air quality impacts related to roundabouts. Emissions can actually be higher at roundabouts, in some cases, as compared to similar traffic flows at signalized intersections.

This Technical Summary pertains to the LRRB-produced Report 2008-24, "Toolbox to Evaluate the Impacts of Roundabouts on a Corridor or Roadway Network," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200824.pdf.



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Principal Investigator: Amiy Varma, North Dakota State University

> **PROJECT COST:** \$71,000



Researchers captured speed data for building a right-turn crash prediction model.



Traffic Volume Thresholds for Requiring Right Turn Lanes and Treatments on Two-Lane Roads

What Was the Need?

When improving or building intersections or driveways on two-lane state highways, local governments and permit applicants must follow criteria established in Mn/DOT's *Road Design Manual* and *Access Management Manual* for what level of traffic triggers the need for right turn lanes. These criteria set thresholds designed to maintain safety near intersections, business driveways and other locations where the main thoroughfare lacks traffic signals or other forms of traffic control.

The manual's current volume warrants are based on engineering judgment rather than quantitative analysis and include volume thresholds that have not been definitively validated by research. As a consequence, it is unclear if the approach to intersection design used by Mn/DOT and local agencies is as cost-effective, safe or efficient as it could be.

There was a need to re-evaluate these policies through a quantitative study and definitively establish the traffic volume thresholds for requiring right turn lanes and related treatments, such as shoulder widening, on two-lane roads.

What Was Our Goal?

The objective of this study was to analyze geometric, traffic, speed and crash data for two-lane roads in Minnesota at locations where the main thoroughfare lacks traffic signals or other forms of traffic control. This data is needed to provide firm empirical grounding for volume-based warrants for the implementation of right turn lanes and other treatments.

What Did We Do?

Researchers focused their analysis on determining the safety and operational effectiveness of right turn lanes and treatments. For the safety assessment, researchers analyzed Mn/DOT crash data, developed a model capable of predicting crashes of different severities caused by right turns, and computed the cost for crashes involving right-turning vehicles.

The crash data included all reported crashes from 2000 to 2002 and 2004 to 2005 on two-lane roads that involved at least two vehicles, as well as a subset of this data for crashes involving right turns. Researchers combined the results of this analysis with Mn/DOT crash cost data to calculate the average cost for crashes involving exclusive right turn lanes (right turn only) and shared lanes (with traffic turning directly from the through lane). They then collected field data at 24 intersections with exclusive and shared right turn lanes to build a model capable of predicting right-turn-related crashes at these types of intersection.

For the operational assessment, researchers examined the effect of right turn lanes and other treatments on delays to through traffic and consequent fuel consumption. Field data was collected at 13 intersections and used in conjunction with CORSIM traffic simulation software and data from Mn/DOT's Office of Investment Management to develop simulation and regression models that calculated the average delays and fuel consumption at these intersections. Researchers then developed 20 provisional, volume-based right turn lane warrants for intersections and commercial and public driveways; these warrants balanced the cost to construct a right turn lane or treatment with the savings gained from reductions in crashes and operational costs.

"The volume thresholds developed in this project provide Mn/DOT with legally defensible criteria for requiring private developers to establish right turn lanes."

-Brian Gage,

Access Management Engineer, Mn/DOT Office of Investment Management

"The warrants developed for this study are sensitive to right turn lane construction costs and fuel prices—key factors that vary over time and with geographic location."

-Amiy Varma,

Associate Professor, North Dakota State University Department of Civil Engineering

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Researchers developed 20 provisional right turn lane warrants for intersections and driveways, establishing thresholds for volume and speed of through traffic (DDHV) and right-turning traffic (RT DHV) for various turn-lane construction and fuel costs.

Construction costs were calculated with the assistance of the technical advisory panel, with savings due to safety benefits calculated as the difference between the total annual cost for crashes incurred because of vehicles turning from shared right turn lanes and the cost incurred from exclusive right turn lane crashes.

Crash costs were computed using a crash severity model in conjunction with crash cost data from Mn/DOT. Savings due to operational benefits were determined by subtracting the total annual costs for delays and fuel consumed during delays at locations with shared movements from the same costs at locations with exclusive right-turn movements. Costs were assumed to be \$13 per vehicle for a typical delay, and \$3 or \$4 for a gallon of fuel.

What Did We Learn?

The study data suggested that adding exclusive right turn lanes and treatments at intersections and driveways could lead to crash cost savings at high-volume locations where about 45 percent of vehicles on the main thoroughfare turn right: more than \$10,000 per year at high-speed locations and \$5,000 per year at low-speed locations. At \$4 per gallon, exclusive right turn lanes could also save more than \$25,000 per year in delay and fuel consumption costs at high-volume locations where about 25 percent of mainline vehicles turn right.

Adding exclusive right turn lanes significantly reduced only rear-end crashes; these had a greater effect on safety at commercial entrances and private driveways than at public intersections.

What's Next?

In the coming months, Mn/DOT will hold discussions about incorporating the results of this study into the *Road Design Manual*. These discussions will incorporate the results of other recent projects, including "<u>How to Determine Optimal Turn Lane Lengths</u>" (2008-14).

This Technical Summary pertains to the LRRB-produced Report 2008-25, "Warrants for Right-turn Lanes/Treatments on Two-lane Roads," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200825.pdf.



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Principal Investigator:

W. James Wilde, Minnesota State University, Mankato Center for Transportation Research and Implementation

PROJECT COST: \$60,080



Researchers compared the stiffness of unbound and stabilized material samples by testing resilient modulus confining pressures in triaxial cells.



Design Procedure for Bituminous-Stabilized Road Surfaces for Low-Volume Roads

What Was the Need?

Gravel roads are common in rural Minnesota. While these roads are sufficient for ordinary low-volume traffic, gravel surfaces offer poor traction and bumpy driving; traffic generates dust and gradually displaces gravel. These roads may also be damaged by heavy farming equipment and other rural industry transportation.

Rural gravel roads can be improved by bituminous stabilization, a process that involves placing up to 10 inches of additional aggregate and mixing its upper 4 to 7 inches with an emulsified asphalt binder. This surface is then treated with a seal coat one to two weeks after compaction.

As Minnesota counties seek to upgrade roads to accommodate heavy equipment and produce better driving surfaces, bituminous stabilization is increasingly becoming more attractive than other alternatives. Maintaining a gravel surface or adding an asphalt overlay may be more expensive in the long term, although a surface with bituminous stabilization needs to be properly maintained: If the seal coats that protect the surface and hold the stabilized layer together are damaged, a more expensive rehabilitation may be required.

Despite the increasing use of bituminous stabilization in Minnesota, its efficacy has not been established by quantitative research, and its design is based on empirical estimates by county engineers. Counties needed a stabilization design procedure confirmed by research.

What Was Our Goal?

The objective of this study was to establish mechanistic design methods for constructing bituminous-stabilized roads. Investigators focused on determining the optimum thickness of the stabilized layer, material properties relevant to design, and the costs associated with construction.

What Did We Do?

Investigators first conducted a literature search of bituminous stabilization practices. They then evaluated stabilized sites in the field, observing construction at two sites and evaluating material samples in the laboratory with tests for soil classification, gradation, moisture content and stiffness. This data was used to identify the costs and benefits of bituminous stabilization of gravel roads.

Investigators then developed software and design procedures for determining the depth to which binder should be mixed with gravel to meet desired load requirements.

Finally, investigators evaluated the respective costs of:

- Maintaining gravel road surfaces
- Maintaining bituminous-stabilized roads
- Overlaying gravel with hot mix asphalt
- Upgrading gravel to HMA over the following stages: an initial bituminous overlay; a 1- to 1-1/2 inch overlay after 5 years; and a second overlay after 12 years

"Under the right conditions, bituminous stabilization improves gravel roads. It eliminates dust; provides a harder, smoother surface; and doesn't lose gravel like unstabilized roads do."

–James Wilde,

Associate Professor, Minnesota State University, Mankato Center for Transportation Research and Implementation

"Regrading and replacing aggregate on gravel roads are expensive measures. This study confirmed the decisions we have been making about bituminous stabilization."

–Alan Forsberg,
 Public Works Director,
 Blue Earth County

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Bituminous stabilization involves laying new gravel and mixing asphalt binder to a depth that supports anticipated loads on a roadway.

What Did We Learn?

In the cost comparison, bituminous stabilization was much less expensive, at \$363 per mile per year for maintenance, than alternatives for maintaining and upgrading gravel roads. A staged upgrade to HMA was the most expensive alternative at \$5,196 per mile per year, followed by maintaining gravel surfaces at \$4,160 and HMA overlay at \$2,460.

Other benefits included smoother driving surfaces and better traction for increased safety; the near elimination of dust problems; a reduction in aggregate loss; a reduction in maintenance costs; and relatively inexpensive upgrades.

There were also several disadvantages to bituminous stabilization, including pavement distress and higher driving speeds on road systems not geometrically designed for safety at these speeds. Despite these disadvantages, researchers concluded that bituminous stabilization is the best choice for maintaining low-volume roads, both economically and in terms of driving quality.

To aid engineers in implementing bituminous stabilization, investigators developed the following design steps for determining the depth to which asphalt binder should be mixed with gravel during construction:

- Use a dynamic cone penetrometer to collect stiffness data at regular intervals along the roadway.
- Determine soil type and gravel thickness.
- Determine expected traffic and the road's required load-bearing capacity.
- Use the data acquired above with the software developed in the course of this study to perform a load-rating analysis of the depth to which asphalt binder should be mixed with gravel to achieve the desired load-bearing capacity.

What's Next?

Because the design procedures established in this study are newly developed, roadways designed and constructed according to them should be monitored over time. Further, more research is required to enhance these procedures by determining design sensitivity to more than one binder source as well as types other than those used in this study; evaluating and improving dynamic cone penetrometer methods; developing and incorporating updated design models; expanding test sites to collect additional data; and identifying fatigue and defining failure for stabilized roadway layers.

This Technical Summary pertains to LRRB-produced Report 2008-28, "Design Procedure for Bituminous Stabilized Road Surfaces for Low Volume Roads," published August 2008. The full report can be accessed at http://www.lrrb.org/PDF/200828.pdf.





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Principal Investigator: Bruce Wilson, University of Minnesota

PROJECT COST: \$89,000



The enhanced simulation program accounts for off-site sediment control tools such as detention ponds to help planners design environmentally responsible construction sites.

Design Tool for Controlling Runoff and Sediment from Highway Construction

What Was the Need?

Storm water runoff from construction sites can degrade the quality of waters in streams and lakes. To protect these valuable resources and limit environmental damage, the Minnesota Pollution Control Agency requires that storm water pollution prevention plans be developed for construction activities that disturb areas of 1 or more acres.

Using best management practices to control runoff sediment from highway construction sites is an important component in construction site design. Understanding erosion processes and implementing erosion/sediment BMPs have been the focus of several research studies sponsored by Mn/DOT and the Minnesota Local Road Research Board. One earlier project to improve the usefulness of experimental data entailed developing a risk simulation tool called WATER (Watershed Assessment Tool for Environmental Risk). WATER simulates the impact of highly variable weather conditions on runoff and erosion for a single construction site.

However, the simulation tool proved to have limitations. Most glaring was the omission from the modeling data of widely used off-site sediment runoff control practices such as detention ponds and rock check dams. Without this data, project planners did not have a complete picture of available practices. Equally important, the simulation tool lacked a user-friendly interface for easy, quick analysis of the runoff data.

What Was Our Goal?

The objectives of the project were to significantly enhance the WATER simulation tool by:

- Incorporating the effects of off-site sediment control practices (those practices taking place a mile or more from the construction site)
- Expanding the WATER model to include processes at a watershed scale by linking together the responses of different land uses
- Developing a more user-friendly interface

What Did We Do?

To include off-site data in the modeling equations, the development team expanded the WATER model to include off-site practices like rock check dams, vegetative filters and detention ponds. In addition, the simulation tool was enhanced to accomplish five types of modeling:

- Risk assessment for a single construction site
- Modeling of multiple land uses within a watershed
- Standalone modules to model off-site processes, including rock and gravel infiltration filters
- Calculations from a feedlot runoff
- Application of a statistical tool to analyze environmental problems

The tool's modeling was also expanded to allow flow and sediment from different areas within a watershed to be combined for determining the overall response of the watershed.

"If not controlled, sediment can impede water flow and reduce water quality. The enhanced WATER simulation tool will provide a more scientific way of defining and managing the erosion risks of construction projects so we can minimize the environmental impact."

-Brett Troyer,

Principal Engineer, Mn/DOT Environmental Services

"We've been recording erosion data for awhile, but not in a useful format. Our new simulation program gives construction planners good information that lends itself to real-world applications."

-Bruce Wilson,

Professor, University of Minnesota Department of Biosystems and Agricultural Engineering

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Creating a new project or running a simulation on an existing one is easy with WATER's project wizard, letting project engineers run simulations against their design to help define, test and, if needed, alter BMPs.

The investigators enhanced WATER to allow users to retrieve and edit input data, carry out continuous simulations, view output results graphically and work with GIS layers. Planners can run extensive simulations for extreme weather conditions—which help to define BMPs—as well as run "what-if" circumstances to determine worst-case scenarios.

In addition, to provide more accurate results, two different algorithms were developed for the WATER model to predict the hydraulic response and removal of sediment in rock and gravel filters.

What Did We Learn?

Enhancements to the WATER risk simulation tool were critically important for practitioners and construction planners. These enhancements provide scientific support for construction design plans and help to define BMPs.

Overall, Mn/DOT was very satisfied with the improvements made to WATER. With the inclusion of both on- and off-site factors, construction planners have a better source of information to develop and test plans. This ultimately leads to construction projects with less environmental risk to neighboring water supplies.

Interestingly, the enhanced WATER program will benefit not just construction planners, but other agencies in Minnesota as well. For instance, the Minnesota Pollution Control Agency will look to the WATER tool to help define water quality standards throughout the state.

What's Next?

While WATER was successfully enhanced to provide a better, more complete source of information for construction site planners, improvements are still needed in its usability. Currently, users need extensive knowledge of what data to input and how to input it to obtain accurate, relevant information. Planning is under way for a second phase of this effort, with the goal of creating a simpler, more intuitive user interface.

Mn/DOT Research Services is considering conducting after-the-fact surveys to gauge the degree to which the workshop facilitated changes in practice at the local level.

This Technical Summary pertains to Report 2008-35, "Design Tool for Controlling Runoff and Sediment from Highway Construction," published August 2008. The full report can be accessed at http://www.lrrb.org/PDF/200835.pdf.



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PROJECT COST: \$108,355



This graph shows how annual road salt purchases for deicing have been increasing for both Minnesota and the nation as a whole.



Environmental Effects of Deicing Salt on Water Quality in the Twin Cities Metropolitan Area

What Was the Need?

The use of salt to deice roadways in winter plays an important role in keeping Minnesota drivers safe. Nationally, salt use has increased dramatically over the last 50 years, with almost 23 million tons of salt spread on road surfaces in 2005. Minnesota spends nearly \$12 million annually on road deicing products, with approximately 350,000 tons of road salt applied in the Twin Cities Metropolitan Area alone.

Sodium chloride, the primary chemical used for deicing purposes, is readily available, inexpensive and has proven effective in maintaining safer roadways; however, its use is not without unintended consequences. Sodium chloride is highly soluble and easily transported over long distances, dissolving in the runoff from roadways and other impervious surfaces and entering ditches, streams or storm sewers. The runoff eventually finds its way into soil, streams, rivers, lakes, wetlands and groundwater. Research has indicated that this can cause concentrations of chloride that have adverse effects on land and aquatic plants and invertebrates.

Knowing more about what happens to deicing salt after it has completed its job of providing for safer winter roadways will allow winter maintenance managers to make more informed decisions as they manage deicing programs.

What Was Our Goal?

The objective of this research was to provide baseline information about the seasonal and long-term effects of the use of road salt on water quality in the TCMA through a salt budget analysis to determine sources of chloride concentration and an analysis of the long-term impacts of deicing salt on the water quality of selected lakes in the area.

What Did We Do?

The project began with a literature review of sodium chloride sources, uses and effects on the environment. Researchers then gathered data on the volume of use of sodium chloride as road salt in the TCMA and related its use to snowfall, lane miles and population.

The team developed a chloride budget (the amount of chloride from all major uses and discharges entering and exiting a watershed) for the TCMA watershed to determine how much of the road salt applied to local roads is exported out of the area by the Mississippi River and how much remains in the area.

Team members examined sodium chloride concentrations in local bodies of water, selecting several lakes for field measurements of chloride and temperature to identify seasonal effects that could be related to road salt application. Finally, researchers analyzed data on chloride concentrations in Minnesota's groundwater from several sources (including the Minnesota Pollution Control Agency, statewide surveys from 1992 to 1996 and 2004 to 2007, county surveys and the Minnesota Department of Health).

What Did We Learn?

The study revealed a strong correlation between the use of road salt and population, as well as between lane miles and annual salt use. Many of the tested lakes had unexpectedly high sodium and chloride concentrations, with the chloride concentrations

"We can use the information from this study to better manage our use of road salt, minimizing impacts while still maintaining safe roadways."

-Wayne Sandberg,

Deputy Director of Public Works, Washington County

"There are many ways we can reduce the rates of salt application, including educating the driving public and road salt applicators, as well as improving application technology and road deicing techniques."

-Heinz Stefan,

James L. Record Professor of Civil Engineering, University of Minnesota

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This map shows the Twin Cities area lakes and their watersheds where researchers analyzed seasonal temperature and chloride concentration levels to try to identify the effects of road salt application.

trending upward. While significant problems have yet to be reported, continuation of the present trend of rising chloride levels will result in certain lakes exceeding acceptable levels of chloride in the future. The lakes exhibited a cycle that corresponds to seasonal road salt applications: higher salinity in winter and lower salinity in summer. Lakes with high chloride concentrations are found in the TCMA core; lower concentrations are found in lakes on the TCMA's periphery.

Approximately 30 percent of the road salt applied in the TCMA is carried away or dissolved by the Mississippi River, leaving 70 percent unaccounted for and assumed to have been retained in local lakes, rivers, streams and groundwater. It is possible, though not proven, that a small amount of the road salt applied in the TCMA is transported out of the area by wind.

Researchers also concluded that shallow groundwater in the TCMA, especially near major roadways, reflects rising chloride concentrations.

What's Next?

Salt has proven effective in maintaining safer winter roadways and plays an important role in winter maintenance operations throughout the state. Results of this study suggest that Minnesota should begin to look for ways to minimize the environmental impact of road salt while still maintaining a focus on safety. Further action suggested by this study includes:

- Evaluation of current operational practices to ensure the most appropriate use of road salt
- Educational programs for road operators that focus on when and how to apply salt
- Evaluation of alternative deicing chemicals

This Technical Summary pertains to the LRRB-produced Report 2008-42, "Study of Environmental Effects of De-Icing Salt on Water Quality in the Twin Cities Metropolitan Area, Minnesota," published September 2008. The full report can be accessed at http://www.lrrb.org/PDF/200842.pdf.



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PROJECT COST: \$63,871



Rumble strips are one of the key techniques for preventing roadway runoffs, a leading cause of crashrelated serious injuries and fatalities.



Putting Research into Practice: Rural Road Safety Solutions Workshop Materials

What Was the Need?

According to U.S. statistics, 43,463 people died in motor vehicle crashes nationwide in 2006, with 2.5 million more injured. On average, 116 people die every day, or one every 12 minutes, in a traffic crash. Even though Minnesota ranks among the states with the lowest traffic fatality rates, Minnesota transportation stakeholders are adamant that traffic fatalities and injuries be reduced. To reach this goal, they established a multiagency partnership called the <u>Toward Zero Deaths campaign</u>.

Most crash-related fatalities and serious injuries in Minnesota occur on the two-lane roads prevalent in rural areas, when vehicles are involved in head-on collisions and roadway departures. Responding to this issue, the Local Road Research Board recently conducted studies relevant to rural road safety. These needed to be synthesized and shared in statewide training designed to make city and county engineers aware of tools and techniques for improving rural road safety, and to help them develop operational cultures focused on safety and data-based decision making.

What Was Our Goal?

The objective of this implementation effort was to maximize the value of Mn/DOT's previous research and available resources by synthesizing information and developing a half-day train-the-trainer workshop along with associated educational materials. These materials would summarize the latest technologies and techniques most suitable for implementing safety improvements on local transportation systems.

What Did We Implement?

The research being implemented through this project was informed by:

- LRRB Report 2006-35, "<u>Safety Impacts Of Street Lighting at Isolated Rural Intersec-</u> <u>tions—Part II,</u>" and <u>its predecessor</u> (Report 1999-17)
- <u>Minnesota Motor Vehicle Crash Facts</u>, which summarizes crash data by location, time and cause
- The Minnesota Strategic Highway Safety Plan
- <u>The Minnesota Crash Mapping Analysis Tool</u>, which enables users to graphically analyze and map crash data by county, city and accident case number
- Mn/DOT's 2007 Highway Safety Improvement Program
- Reports (listed in the <u>workshop</u> deliverable) on safety topics such as pavement markings, lighting, signing, sightline improvements, rumble strips, dynamic speed display signs, animal detection systems, shoulder widening and turn-lane treatments

How Did We Do It?

A technical advisory panel of experts identified key technologies and techniques for improving rural roadway safety. Investigators then performed an extensive literature search on the identified strategies and synthesized these findings.

Panel meetings were convened to focus separately on various technologies and techniques, and investigators produced an outline of the workshop.

"Mn/DOT had recently made rapid advances in developing low-cost rural road safety solutions, and we needed a way to share these techniques with local and county engineers statewide."

-Richard West, County Engineer, Otter Tail County

"We wanted participants to come away from the workshop looking at highway safety entirely differently, in terms of low-cost solutions focusing on the most critical causes of rural roadway fatalities."

-Dave Engstrom,

Workshop Instructor and State Traffic Safety Engineer, Mn/DOT Office of Traffic, Safety and Operations

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ITS Applications: Dynamic Speed Display Signs



The workshop provides guidance on safety tools such as dynamic speed display signs. A presented study showed that drivers on average slowed by approximately 7 mph after these signs were installed at five sites.

Using this data, investigators produced a PowerPoint presentation, participant's manual and instructor's guide, which were then reviewed by the technical advisory panel. Realizing the importance of this workshop and its broad audience, both the Federal Highway Administration and Mn/DOT agreed to be part of the delivery of the workshops.

What Was the Impact?

Eight day-long workshops were presented throughout the state with more than 150 attendees from cities and counties. The course and its expert presenting team, which included the FHWA Safety Engineer for Minnesota, the Mn/DOT State Traffic Safety Engineer, three county engineers and the consultant who developed the curricula, received positive feedback from participant evaluations. Workshop topics were designed to help agencies create an operational culture focused on safety:

- Safety issues on both a local and national level
- Specific safety strategies that engineers can use in their jurisdiction
- Tools and techniques to improve rural road safety and how to implement them
- Ways to secure funding and engage the public in safety issues

Participants were encouraged to focus less on the locations of incidents and more on low-cost solutions to head-on collisions and lane runoffs, which account for most fatal and serious injury crashes on rural roads. These solutions include pavement treatments, wider pavement markings and center line rumble strips.

What's Next?

The Minnesota Local Technical Assistance Program is exploring the possibility of offering this workshop every other year as part of its curriculum and also suggested producing another workshop designed to educate maintenance workers about how their day-to-day activities can make a difference in road safety.

This Technical Summary pertains to LRRB's Research Implementation Committee's product 2008RIC03, "Rural Road Safety Solutions Workshop Materials," published March 2008. The full report can be accessed at http://www.lrrb.org/PDF/2008RIC03.pdf.

The research being implemented through this project can primarily be found in the LRRB-produced Reports 1999-17 and 2006-35, "Safety Impacts Of Street Lighting at Isolated Rural Intersections," Parts I and II, published April 1999 and September 2006, respectively. These reports can be accessed at http://www.lrrb.org/PDF/199917.pdf and http://www.lrrb.org/PDF/200635.pdf, respectively, along with resources as listed above.



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PROJECT COST: \$19,422



Workshop participants discuss case studies like this one requiring rehabilitation of a pavement with severe, 1.5-inch deep rutting.



Putting Research into Practice: Training Module for Pavement Rehabilitation Selection

What Was the Need?

Maintenance engineers have to decide appropriate ways to rehabilitate damaged pavement and sidewalks. Options available for concrete pavements are different from those for asphalt pavements. Many favored options involve recycling techniques, not only for environmental reasons but to save money on materials as well as hauling and processing costs, and to shorten construction time. Three key options are:

- Overlay. The quickest, least expensive and, ultimately, least durable solutions typically involve overlays, which can include a number of options, such as hot-mix asphalt mill and overlay, in which crews grind down 1 or 2 inches of asphalt and replace it with a new HMA layer; fracture and overlay, in which crews fracture pavement slabs to specified sizes and then overlay with HMA or concrete; and concrete on bituminous overlay, in which the surface is repaired and overlaid, or milled down and overlaid. With concrete overlays, joints are cut and, in some cases, dowel bars are used in the new joints.
- **Full Depth Reclamation.** This method requires crews to pulverize existing pavement and use it as a base course for new pavement.
- **Cold-In-Place Recycling.** A method used on low-volume asphalt roads, cold-in-place recycling requires reclaiming the top 2 to 4 inches of pavement in a new, cold-mixed asphalt layer placed over 1 inch of original asphalt.

Various approaches are detailed in specifications and guidelines, but the methods are not easy for engineers to sort through and compare. In January 2008, Mn/DOT and the Local Road Research Board released a report on pavement rehabilitation; this report, combined with a previous manual from 2006, provided Mn/DOT with guidelines for rehabilitation. Creating materials to present the insights of these reports in a classroom setting would help maximize their utility.

What Was Our Goal?

This implementation effort was to draw on completed research, including key Mn/DOT reports and the most current information from around the country, to develop a training module that would guide city and county engineers throughout Minnesota in evaluating pavement repair needs and selecting the most appropriate and cost-effective rehabilitation method. A course on this topic would have the added benefit of providing a venue for continuously updating best practices on a topic that continues to evolve. Training would then occur through Minnesota's Local Technical Assistance Program.

What Did We Implement?

The main Mn/DOT reports used to create the training were:

- "<u>Pavement Rehabilitation Selection</u>" (2008-06), which presented a decision tree for selecting pavement rehabilitation recycling techniques, focusing on the three options described above
- "<u>State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006</u>" (2006-31), which is a concise, definitive handbook that helps city and county engineers select cost-effective rehabilitation methods for concrete roads with low traffic volumes

How Did We Do It?

Investigators drew upon these reports as well as work from various national and industry

"This new workshop helps city and county engineers by streamlining the process of determining what rehabilitation methods best suit pavement or sidewalk repair."

-Michael Sheehan, County Engineer, Olmsted County

"This new course is a companion to the LTAP class on pavement preservation. When the roadway can no longer be fixed, the Pavement Rehabilitation Selection course shows what engineers can do."

-Michael Marti,

Principal, SRF Consulting Group

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Instructors explain best practices such as the train machine concept, illustrated on this workshop slide, where crews work with machines in caravan to recycle old asphalt into a rehabilitated pavement.

transportation sources and consultation with technical experts to create course presentations and materials for a six-hour, one-day training course for engineers.

A pilot workshop was conducted June 25, 2008, at the Hennepin County Maintenance facility in Medina for about two dozen city and county engineers. Investigators Dave Rettner and Dan Wegman led the class while other team members gathered feedback about the training materials.

What Was the Impact

The training session is divided into four parts:

- **Background Information.** Defines terms, sets goals and identifies resources. (15 minutes)
- Understanding the Problem. Focuses on assessing pavement problems, including strength, base and subgrade condition, and drainage. (45 minutes)
- **Rehabilitation Techniques.** Reviews techniques for rehabilitating asphalt and concrete pavement structures. (3.5 hours)
- Making a Decision. Describes decision-making tools and approaches, and includes three case studies for use in group exercises. (90 minutes)

What's Next?

Minnesota LTAP will be using the training module developed in this project for a new pavement rehabilitation selection course, which will be coupled with LTAP's existing pavement preservation training. The two courses will alternate year to year.

Three workshop sessions, all led by Rettner and Wegman, have been scheduled: Grand Rapids, Feb. 24, 2009; Mankato, Feb. 26, 2009; and Medina, Feb. 27, 2009.

This Technical Summary pertains to LRRB's Research Implementation Committee's product 2008RIC04, "Training Module for Pavement Rehabilitation Selection," delivered June 2008. This presentation document can be accessed at http://www.lrrb.org/tools.aspx. The training program will be offered by the Minnesota LTAP and is listed at http://www.mnltap.umn.edu/Events/.

The central reports used to develop this training course were LRRB-produced Reports 2008-06, "Pavement Rehabilitation Selection," published January 2008, and 2006-31, "State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006," published September 2006. They can be accessed in full at http://www.lrrb.org/PDF/200806.pdf and http://www.lrrb.org/PDF/200801.pdf, respectively.



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PROJECT COST: \$21,493



Street sweeping is an important factor in picking up pollutants and debris that would otherwise be washed into local water sources.



Putting Research into Practice: Resource for Implementing a Street Sweeping Best Practice

What Was the Need?

Street sweeping is vitally important to roadway appearance and maintenance, air and water quality, and safety. Streets are the chief collection and removal points for trash; atmospheric and vehicle-related pollution; and debris from lawn and boulevard vegetation, off-site construction, and roadway wear and tear.

Over time, new street sweeping technologies have been developed to deal with changes in environmental regulations and the kinds of discarded items and pollutants prevalent on modern roadways. The proliferation of these technologies provides localities with an often overwhelming number of choices in the kinds of available street sweeping equipment. Local agencies needed a guide to the available options and a decision-making process and policies for creating the most efficient street sweeping operations for their areas. Public works directors also needed enough information to present city councils with budget justifications for what is often a costly municipal service.

What Was Our Goal?

The objective of this implementation effort was to synthesize recent research and develop an easy-to-use technical resource guide summarizing street sweeping practices most suitable for use by Minnesota local agencies. This document would provide content for statewide training through the Minnesota Local Technical Assistance Program.

What Did We Implement?

This project synthesized research identified by Mn/DOT experts as most useful for application in Minnesota. This included three street sweeping reports prepared for <u>Ramsey-Washington Metro Watershed District</u> to help improve water quality within its jurisdiction:

- "<u>Report 1: State of the Practice</u>," which analyzes recent literature and industry expertise on street sweeping methods and equipment
- "<u>Report 2: Survey Questionnaire Results and Conclusions</u>," which summarizes and analyzes 120 responses to a Web-based survey of 16 questions sent to public works practitioners in local governments across Minnesota, other states and Canadian provinces
- "<u>Report 3: Policy Development and Future Implementation Options for Water Quality Improvement</u>," which discusses and incorporates conclusions from the first two reports and makes recommendations for the local government units of Ramsey-Washington Metro Watershed District

Another local reference document drawn upon for this project was the "<u>1994 Metropoli-</u> <u>tan Council's Best Practices for Street Sweeping</u>," which identifies 66 best practices in street sweeping by public works departments in the Twin Cities metropolitan area.

How Did We Do It?

Investigators performed an extensive literature search, and a technical advisory panel of experts was formed to identify street sweeping research studies and reports applicable to most areas of Minnesota. Investigators synthesized this research to develop a draft outline for street sweeping best practices. After review by the panel, this outline was

"Public works directors need information that is detailed, quick to access and applicable for presentation to elected officials. This information was not available for those wanting to improve their street sweeping programs."

-Michael Marti,

Principal, SRF Consulting Group

"Local agencies often lack the budget to effectively address every need, requiring them to find a machine that can best fulfill their most pressing needs most efficiently. This project helps in making those choices."

-Tom Colbert, Director of Public Works, City of Eagan, Minnesota

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The training covered sweeper selection: While higher efficiency regenerative air (see above) and vacuum street sweepers cost more initially than mechanical sweepers, their expected service life is longer.

used to create information sheets and a presentation on implementing or enhancing a street sweeping program. These materials were used for training by the Minnesota Circuit Training and Assistance Program, the mobile arm of the Local Technical Assistance Program.

What Was the Impact?

The final result included four multipage information sheets and a PowerPoint presentation providing guidance about topics such as best management practices, types of sweepers, reasons for sweeping, and sweeping and roadway function. This information is designed to help local engineers and operations supervisors select street sweepers and frequencies of sweeping appropriate to their budget, existing equipment, type and quantity of roadway material generated in their areas, environmental regulations and reasons for sweeping. These reasons could include air quality, water quality, safety, roadway appearance (trash and debris removal) and roadway maintenance cleanup.

Investigators recommended implementing a street sweeping program that involves making use of higher-efficiency technologies, such as regenerative air and vacuum sweepers, for picking up finer particles affecting air and water quality. Because the older mechanical sweepers prevalent in Minnesota are more suited to picking up larger debris (such as leaves), agencies may wish to use older and newer technologies in tandem.

These materials were distributed to city and county engineers as a resource guide for improving their street sweeping programs, were used for training by the <u>Minnesota</u> <u>Local Technical Assistance Program</u>, and were presented at public works conferences and annual meetings of both city and county engineers.

What's Next?

As street sweeping technology continues to advance, information about best practices will need to be updated. Manufacturers are increasingly moving toward sweepers that do not make use of water, including mechanical sweepers that can pick up both fine particles and larger debris.

This Technical Summary pertains to LRRB's Research Implementation Committee's product 2008RIC06, "Resource for Implementing a Street Sweeping Best Practice," published February 2008. The full report can be accessed at http://www.lrrb.org/PDF/2008RIC06.pdf.

The research being implemented via this project can be found primarily in three reports prepared for the Ramsey-Washington Metro Watershed District and published June 2005: "Street Sweeping Report 1: State of the Practice," "Street Sweeping Report 2: Survey Questionnaire Results and Conclusions," and "Street Sweeping Report 3: Policy Development and Future Implementation Options for Water Quality Improvement." These reports can be accessed at the publications page of http://www.rwmwd.org/.



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IMPLEMENTATION PROJECT COST: \$19,389

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The Bridge Tool delivers bridge descriptions (left) and report links (right) via a standard Web browser.



Putting Research into Practice: Creating a New Bridge Information Management Tool

What Was the Need?

Bridge management personnel need access to reliable bridge data, such as hydraulic information about drainage area and flow rate, load ratings, inspection histories, and bridge type and materials, to effectively maintain Minnesota's bridges. To address this need, management launched the Bridge Hydraulic Information database in late 2002. This interactive, geographic information systems-based application allows users to display bridge hydraulic information from state Trunk Highway and State Aid structures using a static database of bridge information.

Authorized users log in to the secure, online database to access bridge data by clicking on a map symbol that represents a bridge. The program displays a map showing the general location of the selected bridge; bridges with information in the database are noted with blue markers. When the user clicks the marker, a report displays all of the hydraulic information available for that bridge.

Mn/DOT saw the opportunity to make the state's bridge design and maintenance work more efficiently by capitalizing on the Bridge Hydraulic Information database to provide greater functionality and more detail about bridges in the system.

What Was Our Goal?

The goal of this project was to create an enhanced Internet-based Bridge Tool that allows the end user to view Mn/DOT's bridge information using a map-based interface. This tool could be employed, for instance, to locate deficient bridges or to develop location maps for general reporting purposes or for applications for bridge funding.

What Did We Implement?

The two most important resources leveraged for this project were:

- The 2002 Bridge Hydraulic Information database, which has been consistently updated with new hydraulic information as it became available.
- The Pontis Bridge Management System, developed in the 1990s under a Federal Highway Administration contract. Mn/DOT uses this system to generate recommendations for least-cost, long-term preservation and improvement policies using collected cost data and information on the condition of bridge elements such as beams, piers and railings.

How Did We Do It?

Investigators began their work with the Bridge Hydraulic Information database and incorporated additional bridge details found in Pontis. They then merged multiple data sets into the Pontis master database to allow for expanded reporting and speedier display of updates. This provided the basis for the new Bridge Tool, which upgraded the original database with:

- Ten new mapping layers for deficient bridges, posted bridges, bridge costs, guardrail, average daily traffic, bridge superstructure type, total bridge length, National Bridge Inventory bridge deck rating, scour codes and legislative districts
- Links from the database to enable the use of Pontis' reporting functions

"Users told us they wanted to see more than just bridge hydraulic information, and they wanted to see it all laid out on a map. The new Bridge Tool does just that."

-Petra DeWall,

Assistant State Hydraulics Engineer, Mn/DOT Office of Bridges and Structures

"The Bridge Tool uses a graphical interface to pull complex information out of a database, giving users a map to work with instead of multiple relational tables."

-Hart Gilchrist, Geographical Information Systems Manager, Bonestroo

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This Bridge Tool screen uses color to show bridge scour codes such as screened as low risk for failure due to scour, screened and determined to be scour-susceptible, and scour-critical.

- Access to hydraulic information for dead or replaced bridges, enabled by the development of a relational table that links the old bridge information with the new bridge number
- A new, user-friendly, Web-based data entry form

What Was the Impact?

The tool's new mapping layers provide much more detail about the state's bridges and greater opportunities for analysis. Users can quickly and easily view details about bridges of interest, and generate Pontis reports about hydraulics, inspections, inventory and other topics. The "Map Tools" function allows users to view all bridges in a particular area of the state. Users can also select a particular bridge element, such as scour code or rail rating, and view all bridges, laid out on a map, coded by color or symbol to denote bridge classifications and ratings.

The new data entry form speeds up the availability of new data. The original Bridge Hydraulic Information database required manipulation of new data before it could be deployed in the application. The Bridge Tool allows Mn/DOT staff to enter data into a form on a Web page and have this information fed directly into the database and broadcasted to the Bridge Tool's Web access point, where it is accessible to users the day after its entry.

What's Next?

The Bridge Tool is now available for use by Minnesota's bridge engineers and engineering technicians and is being presented at the 2008 Minnesota Public Engineers Technology Conference and Tradeshow. Those wanting access to the system should <u>send an</u> <u>e-mail to the State Aid for Local Transportation Help Desk</u>.

The next phase of development for the Bridge Tool is already under discussion. Investigators are looking at ways to provide for interactivity when entering bridge maintenance data and easy data entry while in the field. A change in the application to support incorporation of the Bridge Tool's mapping capabilities into Minnesota's BaseMap is also under consideration.

This Technical Summary pertains to LRRB's Research Implementation Committee's product 2008RIC08, "Development of Scalable Technology to Enhance Transfer of Bridge Information," released in October 2008. For more information on this project, please contact Petra DeWall at petra.dewall@dot.state.mn.us.



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> IMPLEMENTATION PROJECT COST: \$105,000



An LWD repeatedly drops a mass on a loading plate in contact with the ground to estimate its stiffness.

Putting Research into Practice: Using the DCP and LWD for Construction Quality Assurance

What Was the Need?

For a highway to perform well over the long term, its soil and aggregate layers need to provide a stiff, stable foundation. Mn/DOT standards therefore require inspections during construction to ensure that pavement foundation materials have been compacted enough to ensure this condition.

The sand cone test, which measures the density at a single point in a subgrade or base lift, has been used for many years to confirm an inspector's visual inspection. This test can take more than an hour and includes a laboratory component, which pulls the inspector away from the site. New methods to replace this test have been developed that are quicker, can be performed entirely on-site and allow more flexibility by contractors so that construction doesn't have to stop for testing. These new methods are safer for inspectors: Less time kneeling near traffic at a construction site means fewer accidents.

These new methods use devices that accurately measure in-place soil parameters such as stiffness and strength. These properties provide a more representative picture of a pavement's ability to handle traffic loads than laboratory density measurements do, and they allow direct verification of the soil values used during pavement design. Since 1997, Mn/DOT has had a standard for using dynamic cone penetrometers; DCPs test soil strength by driving a metal cone into the ground with repeated drops of a weight. Now, Mn/DOT is also implementing light weight deflectometers, which determine stiffness by measuring the deflection of the ground to a repeatedly dropped weight. Standard, robust LWD and DCP specifications are needed to enable effective transfer of these technologies around the state.

What Was Our Goal?

The objective of this implementation effort was to develop Mn/DOT-approved specifications for using the DCP and LWD in construction quality assurance: to determine the correct placement of the subgrade, granular fill, subbase and base materials.

What Did We Implement?

This project leveraged previous research sponsored by Mn/DOT and LRRB. One primary resource was Report 2006-20, <u>"Validation of DCP and LWD Moisture Specifications for Granular Materials,"</u> which validated the use of DCP and LWD technology. By using these devices on laboratory-prepared pavement specimens, investigators found that the Mn/DOT DCP specification accurately assessed compaction quality and provided some suggestions for improvement.

To develop the specifications, project team members also drew upon two studies that addressed the effect of soil moisture on stiffness and strength: Report 2006-26, <u>"Moisture Effects on PVD and DCP Measurements,"</u> and Report 2007-11, <u>"Pavement Design Using Unsaturated Soil Technology."</u>

How Did We Do It?

Investigators synthesized information from these reports to develop draft specifications and then composed a field test plan to validate the specifications. Two county projects were selected in which DCP and LWD measurements as well as traditional sand cone testing were used to determine strength and stiffness. "These new tools dramatically reduce inspection time for determining the compaction of soils and subgrade applications."

-Lawrence Berkland, Assistant County Engineer, Steele County

"We're happy to be implementing a construction inspection system based on material properties—strength and stiffness—critical to pavement construction and performance."

–**John Siekmeier,** Mn/DOT Senior Research Engineer

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A DCP estimates soil strength by measuring how far a driven metal cone penetrates the ground.

Investigators analyzed the resultant data to validate the draft specifications and test protocols, determining how many DCP and LWD drops should be performed, and how to incorporate factors such as the ground's moisture content and its relative compaction into the analytical process.

What Was the Impact?

This project produced draft specifications that will encourage the adoption of these technologies, which is expected to result in lower life cycle costs for pavements, increased soil compaction uniformity, and higher productivity due to automation. In addition, use of these tests allows increased inspector presence at the construction site, improved inspector safety, and more complete documentation and reporting.

These specifications covered the use of DCP and LWD for granular materials and finegrained soils as well as target stiffness values for the tests to encourage the construction of higher-quality roads.

What's Next?

The draft specifications produced by this project will be further refined and incorporated into Mn/DOT's *Standard Specifications, Grading and Base Manual* and the department's *Geotechnical and Pavement Manual* as well as the inspector and technician certification classes already required for DCP and LWD use. As the benefits of these technologies become increasingly apparent, more and more counties and cities are expected to acquire these tools. LRRB and Mn/DOT have purchased several LWDs that are available for loan to counties and cities.

This project relates to a larger, ongoing <u>Mn/DOT effort to implement intelligent com-</u> paction technology to ensure that Minnesota's roads are constructed with the highest quality at the lowest cost possible.

This Technical Summary pertains to the LRRB-funded report "Using the Dynamic Cone Penetrometer (DCP) and Light Weight Deflectometer (LWD) for Construction Quality Assurance," scheduled for release in October 2008.

The research being implemented via this project can primarily be found in LRRB-produced Reports 2006-20, "Validation of DCP and LWD Moisture Specifications for Granular Materials," published July 2006; 2006-26, "Moisture Effects on PVD and DCP Measurements," published June 2006; and 2007-11, "Pavement Design Using Unsaturated Soil Technology," published May 2007. These reports can be accessed at http://www.lrrb.org/PDF/200620.pdf, http://www.lrrb.org/PDF/200626.pdf and http://www.lrrb.org/PDF/200711.pdf, respectively.

About Mn/DOT's State Research Program

Mn/DOT's mission is to improve access to markets, jobs, goods and services, and to improve mobility by focusing on priority transportation improvements and investments that help Minnesotans travel safer, smarter and more efficiently. Mn/DOT State Research Program funds are allocated to serve Mn/DOT's Strategic Directions:

MN/DOT STRATEGIC DIRECTIONS

Goal 1: Safeguard what exists.

Mn/DOT's most important priority is to operate, maintain and preserve Minnesota's existing transportation systems and infrastructure by:

- **Maintaining** the state's physical transportation assets—highways, bridges, airports, water ports, bikeways and freight, bus, rail and intermodal facilities—in sound and safe condition.
- **Protecting** system performance through effective design, access management, financial support and coordination with local transportation partners.
- Minimizing system downtime due to incidents, construction activities and other disruptions.
- Safeguarding the security of Minnesota's transportation infrastructure.

Goal 2: Make the transportation network operate better.

Mn/DOT aims to implement a balanced, cost-effective statewide strategy to make transportation systems operate better by:

- Advancing investments that improve the safety of the traveling public.
- **Investing** in and improving the system of interregional highway corridors that connect the state's regional trade centers.
- Addressing traffic congestion by improving bottlenecks on the trunk highway system in the Twin Cities' metro area or greater Minnesota.
- **Improving mobility** within highly traveled corridors through investments in transit advantages on trunk highways, incident management and ITS technology.
- **Expanding innovative partnerships** in the construction, delivery and operation of transportation infrastructure and services.

Goal 3: Make Mn/DOT work better.

Mn/DOT will continuously improve service and efficiency to give citizens the best value for their tax dollars by:

- **Encouraging** innovation, competition, privatization, outsourcing, e-government services, and other creative, cost-saving solutions.
- Listening well and being responsive to customers, stakeholders and employees.
- **Managing** for results and being accountable for our decisions and actions. Investments will be driven by current priorities.
- Recognizing and celebrating innovation, responsible risk taking and measurable success.
- Streamlining decision making and right-sizing the organization.

Strategic Vision for Research

With a Strategic Visioning seminar in June 2007, Mn/DOT leaders translated these strategic directions into eight research areas to guide the investment priorities of State Research Program funds through the coming years.

1. Provide a multimodal infrastructure

- Freight
- Truck size and weight
- Commerce direction vs. transportation industry needs
- Effect of de-icing chemicals on vehicles and electronic components: railroad crossings/freight

2. Organization transformation

- Impact of changing demographics/work force
- Change of customer expectations/needs: innovative contracting/quality assurance
- Growing needs and shrinking resources: cost-effective strategies to continue delivering programs
- Mn/DOT organization structure options: regionalization, centralization

3. Innovative project delivery

- Change of culture: increased use of technology, quality, innovation across the organization
- Civil rights: e-bidding
- Remote sensing possibilities
- Accelerated construction: A + B contracting, lane rental, staged construction vs. road closure, rapid bridge or pavement construction methods, prefabricated construction
- Accelerated project development: speed up planning time, increase public input (aesthetics), define Mn/DOT role
- Synthesis of technological advances in data mining/information sharing

4. Traffic safety: low-cost options to zero deaths

- Small, local, low-cost measures
- Speed as a component of bare lane
- Bridge anti-icing systems as part of the design
 process
- Civil rights ADA Title II

5. Infrastructure preservation

- Improve management, lower life cycle costs
- Cost-effective pavement preservation best practices
- Optimization of recycled materials
- Cumulative bridge overloading
- Preservation of modal infrastructure: transit systems, bike trails infrastructure, pavement, bridges and roadside assets
- Cheap pavements that don't crack

6. Responding to customers and stakeholders

- Building public confidence: ensuring agency credibility
- Finance and revenue innovation: corridor agency, private funding, GCA California model, innovative funding sources (private sector, European bonds, etc.), "mileage-based" concept
- Impacts of higher gas prices: Decrease in miles traveled, need for new funding sources
- Transportation infrastructure and economic development
- Improved legislative transportation decision processes

7. Green roads

- Green roads: both construction and maintenance, environmental stewardship, implementing technologies to reduce global warming
- Water management and roadsides: preserve critical roadside/water management infrastructure
- Energy efficiency: best practices for low-cost roadway lighting, hybrid vehicles in the snow fighting fleet, self-supplied/solar energy for road/sign/in-pavement lighting
- Clean water practices: NPDES Phase II permit requirements, long-term maintenance and impacts of environmental Best Management Practices
- Environmental forecasting management systems

8. Congestion management

- Benefit/cost evaluation, low-cost fixes vs. major projects
- A + B contracting
- Design-build
- Demand management: Optimize current road system, congestion pricing
- Optimizing cost-effectiveness of shoulders



Two Mn/DOT research reports completed this year looked into the rationale and design for turn lanes. Report 2008-14 computed optimal turn lane lengths for intersections with particular characteristics, while Report 2008-25 focused on how much traffic at an intersection warrants implementation of a right turn lane. In this latter study, researchers examined existing crash data and then collected speed and other data (pictured) at 24 intersections with exclusive and shared right-turn lanes to create a right-turn crash prediction model.

2008 State Research Program Reports and Implementation Products

Research Services is pleased to have published the following products in 2008. Each bolded report below is discussed in a two-page Technical Summary presented in this section:

2008-01	Compaction Remediation for Construction Sites		
2008-04	Wet Meadow Revegetation Following Invasive Plant Control		
2008-05	An Inventory of the Public Land Survey Records for Minnesota: The Special Instructions		
2008-07	Effects of Center-line Rumble Strips on Non-Conventional Vehicles		
2008-09	Improving Capacity Planning for Demand-Responsive Paratransit Services		
2008-10	Pavement Evaluation Using Ground Penetrating Radar		
2008-11	Access to Destinations: How Close is Close Enough? Estimating Accurate Distance Decay Functions for Multiple Modes and Different Purposes		
2008-12	Development of Measurement Sources for Freight Performance Indicators		
2008-13	Methods to Incorporate Historic Surface Hydrology Layer in Mn/Model [Phase 4] Using Existing Geographic Informa-		
	tion System Data		
2008-14	Turn Lane Lengths for Various Speed Roads and Evaluation of Determining Criteria		
2008-15	Access to Destinations: Twin Cities Metro-wide Traffic Micro-simulation Feasibility Investigation		
2008-16	INV 817: Determination of Optimum Time for the Application of Surface Treatments to Asphalt Concrete Pavements—Phase II		
2008-17	Cross Median Crashes: Identification and Countermeasures		
2008-18	MnROAD Cell 54—Cell Constructed With Mesabi-Select (Taconite-Overburden) Aggregate: Construction and Early Performance Report		
2008-19	Access to Destinations: Parcel Level Land Use Data Acquisition and Analysis for Measuring Non-Auto Accessibility		
2 008-21	Development of a Trash Harvester for Mn/DOT—Phase II		
2008-22	Intelligent Compaction Implementation: Research Assessment		
2008-23	INV 857: Effects of Seasonal Changes on Ride Quality at MnROAD		
2008-25	Warrants for Right-Turn Lanes/Treatments on Two-Lane Roads		
2008-26	Access to Destinations: Monitoring Land Use Activity Changes in the Twin Cities Metropolitan Region		
2008-29	LED Lighting for Snow Plows and Related Maintenance and Construction Vehicles		
2008-33	The Impact of Bicycling Facilities on Commute Mode Share		
2008-35	INV 833: Design Tool for Controlling Runoff and Sediment from Highway Construction		
2008-36	Generational Perspective on Teen and Older Drivers on Traffic Safety in Rural and Urban Communities		
2008-37	Developing and Implementing Enhanced Pavement Marking Management Tools for Mn/DOT: Phase I—Mapping Tool		
2008-39	Production and Wind Dispersal of Canada Thistle (Cirsium arvense L.) Achenes		
2008-40	Best-Value Based on Performance		
2008-41	Monitoring and Analysis of Mn/DOT Precast Composite Slab Span System (PCSSS)		
2008-46	Evaluation of Concrete Pavement Texturing Practices in Minnesota Using the Wet Weather Accident Evaluation Criterion		
2008-47	Corrosion Protection Performance of Epoxy-Coated Reinforcing Bars		



Mn/DOT supports several projects to protect Minnesota's environment, including an effort recorded in Report 2008-48, Improved Methodologies for the Inoculation of **Prairie Legumes** in Roadside/ Revegetation Settings. Prairie plantings like this one help in the fight against global warming, and prairie restoration is critical for agricultural and wildlife maintenance. This study produced recommendations for the best inoculating bacteria to use to protect the legumes that are integral for prairie development.

Mn/DOT has sponsored research into ground penetrating radar (such as in Report 2008-10); this technology can determine pavement thickness and other properties, and can locate subsurface objects without the need to shut down the roadway and remove pavement samples.





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PROJECT COST: \$178,524



Researchers measured the water infiltration rate and soil strength to assess the effectiveness of the tilling procedures.

Compaction Remediation for Construction Sites

What Was the Need?

While building highways, heavy machinery passes over the ground next to the road many times, severely compacting the soil. This results in poor drainage, inhibits the growth of vegetation and causes erosion. Managing the storm water runoff from highways and compacted rights of way may require the purchase of additional land, which is often a significant expense in construction projects. Holding ponds built to manage storm water runoff are also expensive and need regular maintenance.

Once a highway is complete, the rehabilitation of the land in the ROW routinely includes reseeding with native plants and grasses, many of which have deep roots that are severely inhibited from growing properly by heavily compacted soils. Deep tilling of the soil by various methods has been shown to be a low-cost method to improve water infiltration, reduce runoff and enhance crop growth in agricultural applications. This practice offers a promising avenue for ROW rehabilitation.

What Was Our Goal?

The objective of this study was to develop a tilling protocol for ROW areas that would enhance drainage and be compatible with current erosion control methods. This should reduce the size and number of required holding ponds, and increase the effective use of current resources.

What Did We Do?

Researchers selected highway construction sites with a variety of soil types, grades and development of vegetation, all of which exhibited poor water infiltration according to Mn/DOT personnel. The sites and soil classifications were:

- Highway 169-TH 19, Belle Plaine (clay loam, established vegetation)
- Highway 319, Brainerd (sandy loam, established vegetation)
- Highway 14-County 3, Janesville (clay loam, newly constructed)
- MnROAD facility, Albertville (silty loam, established vegetation)

One-acre test plots were established at each site representing three major soil types: sand, silt and clay. Three indices were used to characterize the benefits of tillage:

- Soil strength, measured with a tractor-mounted soil cone penetrometer
- Water infiltration rate, measured as the time required for a given amount of water to seep into the ground (the Philip-Dunne method)
- The amount of vegetative growth, which researchers quantified by analyzing digital photographs

Three tillage methods corresponding to three different pieces of equipment were compared to nontilled soil:

- DMI Chisel Plow: five tines, 30-inch spacing, 12-inch operational depth
- Kongskilde Paraplow: four tines, 36-inch spacing, 18-inch operational depth
- Caterpillar Subsoiler: two tines, 36-inch spacing, 24-inch operational depth

Data was collected and the sites were evaluated over two growing seasons following the tillage treatment.

"Sometimes the ground was so hard you couldn't pound a nail in it."

-Dwayne Stenlund, Natural Resource Specialist and Senior Ecologist, Mn/DOT Environmental Services

"Planning the right of way to minimize the presence of utilities and construction waste would have a big impact on the effectiveness of the tillage."

-Jonathan Chaplin,

Associate Professor, University of Minnesota Department of Bioproducts and Biosystems Engineering

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Investigators used three plows—with varying tine depths and tine types—to till the soil types examined in the project. The DMI chisel plow (shown above) operates at 12 inches deep.

What Did We Learn?

The study showed that soil type governed whether tilling improved infiltration. No measurable differences in soil strength were detected between the tilled and nontilled soil, regardless of soil type. Tilling improved water infiltration rates, but primarily in sandy soil; marginal improvement was observed in silty soil, with almost no change measured in clay soil.

In sandy soil, results indicate it would be possible to reduce the ROW area by up to onethird if infiltration is the only consideration. Vegetation coverage improved after tilling. The Paraplow, which does not invert the soil during tilling, left the original vegetation relatively undisturbed and had a significantly better aesthetic appeal than the other tilling methods.

A limited cost analysis showed that the cost of tilling would range from \$11/acre to \$33/acre. This was judged to be minimal compared to the savings from purchasing smaller areas of land for ROW access.

What's Next?

Researchers made several recommendations for future best management practices:

- Restricting and regulating the distribution of utilities in the ROW would make tilling more consistent, effective and cheaper.
- Tilling should only be performed in dry conditions to avoid inhibiting rather than increasing infiltration.
- Piles of heavy clay, disposed concrete and other debris relocated to the ROW during construction detrimentally affect the water infiltration patterns and the ability to properly till the soil. Managing material and debris relocation at construction sites would improve the reliability of tillage efforts and make tilling easier.

Implementation of tilling in some ROW areas is in progress, particularly in haul roads and staging areas on construction sites, using the noninverting Paraplow.

This Technical Summary pertains to Report 2008-01, "Compaction Remediation for Construction Sites," published January 2008. The full report can be accessed at http://www.lrrb.org/PDF/200801.pdf.



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Principal Investigator: Rod Squires, University of Minnesota

PROJECT COST: \$32,283



The fragility of many of the letter books inventoried through this study limits digitization options.

An Inventory of the Public Land Survey Records for Minnesota: The Special Instructions

What Was the Need?

The public land surveys that established the legal framework for real property descriptions and titles in Minnesota were performed between 1847 and 1908 by deputy surveyors under the supervision of Surveyors General. These deputies were guided by instructions received with their contracts, and the Surveyors General also received various instructions from their superiors, the Commissioners of the General Land Office. The correspondence among these individuals is often referred to as "Special Instructions."

These instructions are crucial for accurate reconstruction of the original survey lines and corner monuments; this information is especially important for Mn/DOT's boundary surveys. They are seldom used, however, because they are in paper format and scattered in repositories across the country. Government officials, land surveyors, attorneys and private citizens need to be able to access these records easily, and modern digital imaging, geo-indexing and the Internet offer promising avenues for addressing this need.

What Was Our Goal?

The main objectives of this research were to:

- Locate and categorize the Special Instructions given to the deputy surveyors who ran the public land survey lines and established the corner monuments in Minnesota.
- Compile an inventory of these instructions and acquire illustrative samples of these records.
- Identify the most practical, cost-effective way to make the instructions electronically available with a minimum of handling.

What Did We Do?

Researchers conducted a preliminary inventory of the Special Instructions, especially those documents included in the correspondence files maintained by:

- The Surveyors General of Wisconsin and Iowa, located in the Iowa State Archives, Dubuque.
- The Surveyors General of Minnesota, located in the Minnesota State Archives in the Minnesota History Center, St. Paul.
- The Commissioners of the General Land Office, housed in the National Archives, Washington, D.C.

The inventory provided a preliminary index to the various record collections in the three locations. It contained description and analysis of some of their contents, and assessed their quantity and condition. Researchers took digital photographs of representative samples of records and made recommendations for producing digital images of these collections.

What Did We Learn?

The project report notes that there is some difficulty in differentiating, with absolute certainty, the Special Instructions from other instructions in the correspondence. Therefore, the researchers recommend that all letters between the Commissioners of the

"Inventories of the survey records, along with an organizing framework, are necessary prerequisites for any meaningful analysis and application of the original survey data."

-Rod Squires,

Associate Professor, University of Minnesota Department of Geography

"Electronic access to these vitally important documents that address land title and boundary definition will enhance the efficiency and effectiveness of land surveyors and those dependent on them while also working to improve the integrity of Minnesota's vital legal framework for real property."

–Jay Krafthefer,

Right of Way Supervisor, Mn/DOT Office of Land Management

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The Iowa State Archives contains letters like these from deputies to the Surveyors General that are associated with earliest public land surveys in Minnesota.

General Land Office, the Surveyors General and the deputies be digitized.

Digital photography is permitted in each repository, and is the easiest and cheapest way to make images of the records. This option is preferable to scanning because many of the letters are compiled in bound volumes, some of which could be damaged during a scanning effort. Digital photography requires less handling of the records and can produce high-quality color images of both single letters and letter books. The most timeconsuming part of the process will be making an index of all the images created.

This process can be streamlined by first compiling lists of the surveying deputies who carried out the work; the dates of all the contracts relating to surveys in specific areas; and circulars and other letters that the Commissioners sent to all Surveyors General.

What's Next?

The goal of the larger research effort that includes this project is to create an electronic database for all records relevant to public land surveys in Minnesota. Incorporating a spatial index into this database would provide optimal access to this resource, allowing users to find documents by location using public land survey corners, lines, sections, townships and other instructions.

The current study shows how these valuable records can be made available to modern land surveyors and others who seek a deeper understanding of how the surveys were carried out in Minnesota. In cooperation with Mn/DOT, the University of Minnesota has reallocated some funds received for this project to a follow-up effort to digitally capture the letters containing Special Instructions in the Iowa State Archives. This process will serve as a model for handling similar records in other repositories, both for Minnesota and for other locations.

This project is a crucial part of a broader effort involving cooperation among multiple agencies and interest groups seeking to preserve, convert and improve access to the entire General Land Office record collection. Other aspects of the collection include the General Land Office plat maps (already available <u>on the Web</u>) and General Land Office field notes (comprising more than 275,000 pages).

This Technical Summary pertains to Report 2008-05, "An Inventory of the Public Land Survey Records for Minnesota: The Special Instructions," published May 2008. The full report can be accessed at http://www.lrrb.org/PDF/200805.pdf.



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Principal Investigator: Kenneth Miller, St. Cloud State University

PROJECT COST: \$27,568



At 4 inches wide, 3 inches long and 2 inches deep, centerline rumble strips are not easy to spot.

Effects of Centerline Rumble Strips on Motorcycles

What Was the Need?

Centerline rumble strips—grooves that are milled into roadways between lanes—alert drivers when their vehicles wander. They have proven effective in reducing accidents caused by vehicles crossing over into opposing traffic. Mn/DOT has installed these strips on several hundred miles of roadways, slowly phasing the practice in over a period of years.

However, Mn/DOT has not established a specific policy for using centerline rumble strips. One critical element that must be understood before establishing such a policy is their safety for nonconventional vehicle drivers. The impact of rumble strips on motorcycles and three-wheelers had not previously been studied, but over half of all motorcycle accidents in the country are accidents involving only a single vehicle (that is, the motorcycle). Cyclists and engineers have expressed concern that rumble strips may startle riders and cause accidents caused by overcorrection or other responses.

National accident data and research have established driver overcorrection as the primary cause of 2.5 percent of motorcycle crashes in Minnesota and 4.4 percent of these crashes nationally. Rumble strips have not been found to cause stability concerns for cyclists, leaving rider behavior as a central factor in such accidents.

What Was Our Goal?

The objective of this project was to determine if centerline rumble strips contribute to cyclist accidents or negatively affect motorcycle rider behavior. If cyclists are endangered in any way by rumble strips, their design may need to be adjusted to accommodate nonconventional vehicle operator needs.

What Did We Do?

This investigation involved three steps:

- First, researchers analyzed accident data from 1999 to 2006 in Minnesota, matching motorcycle accident sites to the presence of rumble strips and evaluating whether rumble strips may have been a factor in such accidents.
- Second, researchers performed observations of rural highways with centerline rumble strips. Direct observation and video recording drew together 44 hours of data focused on centerline crossing and rider behavior.
- Finally, investigators conducted a controlled observation of rider behavior on a 1-mile closed course that included two sections of centerline rumble strips. Thirty-two riders of touring, cruising and sport bikes (including two new riders) as well as two riders of three-wheeled vehicles were put through the course without being told the focus of the study.

What Did We Learn?

Minnesota accident data includes 9,845 motorcycle crashes from 1999 to 2006. Rural rumble strips were present in 29 of these accidents, one of which took a rider's life. Not one accident report mentioned rumble strips as a factor, and all but two had clear causes unrelated to rumble strips. In only three accidents was road surface even a potential factor.

"We want to establish a policy for where to use centerline rumble strips, so we hired a researcher to investigate the safety impacts of what we have installed."

-Dave Engstrom,

State Traffic Engineer, Mn/DOT Office of Traffic, Security & Operations

"We weren't able to find any evidence that centerline rumble strips cause problems when motorcyclists cross them. New riders are sometimes nervous about them, so we may want to include the strips in training or license examinations."

-Kenneth Miller, Assistant Professor, St. Cloud State University

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Investigators observed motorcyclists circuit a 1-mile course with rumble strips, marked here by rectangles.

Roadside observation yielded a small number of rumble strip crossings, and no instances of directional changes or unusual riding behavior during crossing. Rumble strips did not seem to inhibit any passing opportunities.

Closed-course examination showed no steering, braking or throttle adjustments during strip crossing. Postride interviews confirmed these observations, and no rider expressed difficulty or concern with crossing rumble strips. Half of the riders noticed the strips before crossing, but no rider described the strips as a hazard either on the closed course or on public roads, though eight found them a nuisance when passing another vehicle.

After analyzing the data gathered in this study, the investigators concluded that there was no indication that centerline rumble strips pose a hazard to cyclists, and that warning signs are unnecessary. New riders, however, may react negatively to the strips. Including rumble strips in motorcycle safety courses and driving examinations should address this concern.

What's Next?

This research essentially puts the question of centerline rumble strips' safety impacts on motorcyclists to rest. There is no need to post signs warning of the presence of these strips. Mn/DOT may encourage the Department of Public Safety to require the inclusion of centerline rumble strips in cyclist safety courses or examinations.

However, an official Mn/DOT policy on centerline rumble strips is not yet feasible, as maintenance crews have expressed a number of concerns about rumble strips for winter plowing and deicing. For instance, the grooves have changed deicing salt truck passing practices and increased the amount of salt used in certain cases. By trapping moisture and snow, the strips may contribute to occasional irregular ice patches on roadways. Moreover, snowplows damage pavements by catching the edges of the strips. Research is needed to investigate these issues before an official Mn/DOT policy can be established.

An element present in the investigators' contract for this project that did not appear in its execution was the consideration of the effects of rumble strips on hand-control handicap vehicles. Further study would be required to gain the insight Mn/DOT desires in this area.

This Technical Summary pertains to Report 2008-07, "Effects of Center-Line Rumble Strips on Non-Conventional Vehicles," published January 2008. The full report can be accessed at http://www.lrrb.org/PDF/200807.pdf.





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Principal Investigator: Diwakar Gupta, University of Minnesota

PROJECT COST: \$55,000



Minnesota statutes go beyond ADA mandates, requiring a larger paratransit service area, and more intensive pickup and drop-off services.

Improving Capacity Planning for Demand-Responsive Paratransit Services

What Was the Need?

The Americans with Disabilities Act mandates that communities with federally subsidized public transit systems must offer on-demand paratransit services for people with disabilities. Paratransit services must match the hours of operation of public transit, minimize service denials because of capacity shortages and maintain additional service quality measures beyond those applicable to public transit such as on-time pickups and drop-offs and acceptable ride times. Metro Mobility, the agency that provides paratransit services to the Twin Cities area through two contractors (Laidlaw and Transit Team), is also anticipating an additional same-day service requirement by the Federal Transit Authority.

To comply with these regulations and contain rising operating costs, it is essential that paratransit service providers schedule the most efficient routes and perhaps consider new ways to meet service demands. The tools necessary to make these improvements, however, are not built into existing software that these providers use for scheduling and creating routes.

What Was Our Goal?

This project was initiated to create three products:

- A mathematical model for computing the level of service obtainable with each level of expenditure on dedicated paratransit service providers and nondedicated services such as taxis
- A framework for choosing the right mix of dedicated and nondedicated services
- A methodology to help paratransit service providers estimate resources required to respond to increasing demand and to move toward the goal of same-day service

What Did We Do?

Researchers began by analyzing archived paratransit performance data, looking for correlations between metrics to identify patterns that could lead to operational improvements. The reviewed data included:

- Records of cancellations, no shows and overall productivity from January 2001 through August 2005
- Customer booking data and contractor productivity measures for 2004 and 2005
- Financial information on bonuses and damages for all of 2004 and the first eight months of 2005

Researchers also studied whether service providers could improve route efficiency. They analyzed historical trip data for one day of operations for each of the two service providers. On June 1, 2005, Laidlaw served 1,009 passengers on 103 routes. Transit Team served 1,534 passengers on 110 routes on May 9, 2007. Of those, researchers used 85 and 66 routes, respectively, as a proof of concept, as the remaining routes violated one or more service-level requirements.

Reviewing this data and accounting for additional parameters set by Metro Mobility and ADA requirements, researchers began building a reoptimization algorithm. Then they used this algorithm to resequence stops along each route and move passengers from one route to another. Researchers applied the algorithm to improve efficiency on individual

"This research shows that we can reduce costs by reoptimizing customer pickups and drop-offs, swapping trips between scheduled routes, and allowing some customers to travel by taxi without affecting promised pickup and drop-off times."

-Diwakar Gupta,

Professor, University of Minnesota Department of Mechanical Engineering

"Beyond its immediate utility for Metro Mobility, this study also has the potential for improving rural public transit service."

-Sarah Brodt Lenz, Program Administrator, Mn/DOT Office of Transit

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The reoptimization model (above) designed for this project can improve route efficiency. In this example, reoptimization saved about 45 minutes of travel time.

routes (a "first-pass" algorithm), and also explored a more time- and labor-intensive way of applying the algorithm to improve two routes simultaneously (a second-pass algorithm). Reoptimizing routes leads to greater efficiency and fewer hours needed to serve all customers.

Researchers also developed a procedure to identify preferred passengers who could be offered the option to travel by taxi at no additional cost. This procedure was then tested in a computer simulation where the probability that a passenger would accept the taxi offer could be changed; this allowed researchers to develop a more realistic estimate of potential savings.

What Did We Learn?

The models and algorithms developed for this study can be used to help implement two approaches for improving efficiency: reoptimizing Metro Mobility routes and selectively using nondedicated service providers.

By using the reoptimizing approach with just the simpler first-pass analysis alone, which can be done on a daily basis during the overnight hours, Metro Mobility could save 5 percent of its operating costs. In 2004, Metro Mobility's operating costs were \$19.5 million, so anticipated savings would have netted \$975,000.

Additionally, by supplementing paratransit services with nondedicated service providers, Metro Mobility could save hundreds of dollars per day, depending on the proportion of customers who agree to travel by taxi.

After completing the handbook update, researchers created a two-hour course providing an overview of this new resource for deployment through the Minnesota Local Technical Assistance Program.

What's Next?

Researchers created computer codes that can be automated by a programmer who knows Metro Mobility's current system to allow reoptimization of the routes at the end of each day of booking. Investigators also recommend a pilot program to better understand what proportion of passengers would accept an offer to travel by taxi.

Another researcher recommendation concerns examination of Metro Mobility's paratransit contract parameters. Currently, contractors can earn more by lowering their productivity during low-demand periods; contract adjustments are needed to remove this incentive misalignment.

This Technical Summary pertains to Report 2008-09, "Improving Capacity Planning for Demand-Responsive Paratransit Services," published April 2008. The full report can be accessed at http://www.lrrb.org/PDF/200809.pdf.



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Bojan Guzina, University of Minnesota Joseph F. Labuz, University of Minnesota

PROJECT COST: \$96,000



Researchers used a percometer to measure dielectic constants in order to find correlations with pavement and soil material properties.

Pavement Evaluation Using Ground Penetrating Radar

What Was the Need?

Pavement engineers use ground penetrating radar to determine physical properties and characteristics of the pavement or subgrade. GPR helps engineers to determine the thickness of a pavement structure without resorting to excavation, and it has the potential to find utilities and other subsurface objects.

GPR can be mounted on a moving vehicle. Instead of shutting down a section of roadway, cutting out (coring) a number of samples, putting workers at risk and inconveniencing motorists, engineers can perform subsurface surveys with a GPR van operating at 50 mph. Another advantage of GPR is that it produces continuous data for pavement survey. Coring, in contrast, only provides data on a 6-inch diameter pavement sample; many cores may be required for a 1-mile pavement survey.

GPR identifies the types of materials detected using a material property called the dielectric constant, which describes a material's ability to propagate electromagnetic waves. When the dielectric constant of two materials is similar, as is the case for aggregate and concrete cement, radar waves reflecting off those materials can be difficult to distinguish. GPR readings are not, therefore, always reliable and must be carefully compared to records of pavement design and construction activity.

What Was Our Goal?

The goal of this project was to develop new, more accurate algorithms for backanalyzing GPR field measurements performed on paved roads. These algorithms would need to efficiently translate GPR images into reliable information about the thickness of the asphalt concrete and aggregate base layers, and the mass density of the asphalt concrete layer. The algorithms should also present engineers with a clear picture of pavement distress, such as instances of delamination.

These findings should enable development of more accurate uses of GPR in assessing pavement thickness and the presence of subsurface anomalies even in cases where pavement records may not be available and coring is limited or absent.

What Did We Do?

Researchers analyzed past methods of interpreting GPR data and developed a new approach using sophisticated electromagnetic waveform analysis methods and an appropriate backcalculation model. This involved developing pattern-recognition technology that can be used on a pavement system without prior dielectric layer information, as well as a computer model that generates synthetic GPR time histories. These histories were tested in an algorithm that derives pavement layer thicknesses, dielectric constants and specific forms of damage from such data.

Researchers identified correlations in data and adjusted backcalculation methods for more accurate interpretation of GPR data.

What Did We Learn?

The computer model developed for this study generates synthetic GPR time histories for a wide range of pavement profiles, as characterized by layer thicknesses, dielectric constants and specific forms of damage. The resultant database of synthetic histories has been used in pattern-recognition software that can analyze measured pavement time histories to instantly identify the pavement as fitting a particular profile. This procedure "This technology is great. If you want to redesign a distressed pavement, you have to know the pavement's thickness. This gives us a continuous profile of the pavement rather than information from specific cores at a limited number of points."

-Shongtao Dai,

Mn/DOT Research Operations Engineer

"Unlike the traditional GPR method, this emerging technology can be deployed with no prior information about the pavement system's dielectric layer properties. It carries significant potential to evaluate pavement distress."

-Joseph F. Labuz, Professor, University of Minnesota Department of Civil Engineering

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GPR is mounted on a van and gathers pavement structural data, such as thickness, at 50 mph so workers don't need to close traffic lanes to cut out multiple pavement samples.

does not require any prior information or assumptions about the pavement system, such as dielectric layer properties, nor does it require subjective image adjustments.

This study enabled researchers to refine the backcalculation method and deliver a calibration system based on the height of the GPR unit during the survey. This method provides a way to measure pavement thickness at far less cost, inconvenience and risk to workers than coring. It measures conditions in the field without the need for pavement design or construction records.

What's Next?

With further refinement and corrections, the tools developed for this study will be applicable to Mn/DOT's GPR data analysis: Mn/DOT already advises regional engineers to use GPR for pavement profiling—particularly in determining asphalt layer thickness—and for locating utilities.

Using the GPR time history database to classify pavements offers significant potential for evaluating pavement distress, including delamination. Accuracy in this area is particularly important in situations where fluctuations in moisture levels within the pavement system can lead to a serious misdiagnosis and unnecessary rehabilitation.

Other diagnostic uses for GPR—and other non-GPR methods for determining dielectric constants—could be developed to further refine GPR use.



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Principal Investigator: Amiy Varma, North Dakota State University

> PROJECT COST: \$69,000



Trucking increasingly dominates U.S. freight transportation, accounting for 58 percent of freight tonnage in 2002, up from 54 percent in 1993.

Assessing Mn/DOT's Freight Performance Measures

What Was the Need?

Freight is playing an increasingly important role in transportation planning at local, state, regional, national and international levels. As the shipping of commercial and industrial goods becomes more global, it is more dependent on varying infrastructures and operational and logistical systems. Planners must determine if these transportation systems are capable of moving freight effectively and safely.

Mn/DOT currently uses four performance indicators, identified in the <u>2005 Statewide</u> <u>Freight Plan</u>, to assess Minnesota's freight transportation system: shipment rates; mode share, or the percentage of freight moved by a particular mode of transportation; geographic market share; and travel time.

Because of current difficulties in accurately obtaining and modeling freight data, these performance measures need to be evaluated for their clarity, technical adequacy, and the cost and availability of the data required for their application. Additional measures that may be useful also need to be identified. This assessment will assist Mn/DOT's long-range planning efforts to improve its freight transportation system and update the Statewide Transportation Plan.

What Was Our Goal?

The objective of this project was to evaluate Mn/DOT's current freight performance measures by identifying more general industry measures and finding available public and private sector freight information sources required for the application of these measures. In addition, the project assessed the cost of using these information sources and examined the relevance of source data to Mn/DOT and freight movement within and through Minnesota.

What Did We Do?

Investigators conducted a literature review to identify performance measures currently in use by industry. They then identified public and private data sources for these measures and classified them according to mode, market, commodity, provider and performance measure category.

Researchers then assessed the relationship between the various performance measures identified in the previous step and their data sources, the availability of data, the cost of acquiring it and its relevance to Mn/DOT. Finally, they used these analyses to recommend best practices for Minnesota and to identify lessons learned from other efforts, freight industry data and reports to monitor on an ongoing basis, and additional prospective measures that Mn/DOT should further develop.

What Did We Learn?

Researchers found that freight performance measures are often not clearly defined, and it may be costly to develop and maintain the data required to use them. Moreover, freight modes are continually in flux, and much of the data required for developing measures is proprietary or withheld for security reasons. To address these challenges, researchers identified the best sources for freight performance data—including federal databases, past freight studies and information available from the economic development department—and recommended best practices for developing measures, including:

• Identifying the policies and strategic objectives in statewide and district freight plans

"By comparing external data to existing Mn/DOT data, we gained a much better understanding of our performance measures. This data is critical to compiling the state's transportation plan."

-Robert Gale,

Planner Principal Transportation, Mn/DOT Office of Freight and Commercial Vehicle Operations

"It can be costly and difficult to obtain the data required to use performance measures. This study helps overcome this challenge by identifying the best data sources and practices for developing the measures most relevant to Mn/DOT's needs."

-Amiy Varma,

Associate Professor, North Dakota State University Department of Civil Engineering

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Example Performance Measure/Indicator	MD.3 Value of shipments to Minnesota by major commodity groups by different Modes
Goal/Strategic Direction (s)	Strategic Direction 2 – Make the network operate better Strategic Direction 3 – Make Mn/DOT work better
Policy(Policies)	Policy 4 – Provide cost-effective transportation options for people and freight Policy 9 – Inform, involve and educate all potentially affected stakeholders in transportation; Plans and Investment Decision Processes.
Sector(s)/Commodity(ies)	Various
Mode(s)	All
Market(s)/Decision Context(s)	Global,Multinational, National, Multistate, Statewide, Regional
Type of Movement(s)	Only freight
Usage	Currently being used In Minnesota (Policy 4, PI3 MNSFP) - Performance Indicator
Domain(s)	Private
Maturity	Not Mature
Measurement Source(s)	Past Freight Flow studies provided snapshots; CFS, Global Insight's TRANSEARCH-INSIGHT data, local surveys; FAF data
Challenges	So far snapshots have been developed almost at 5 year interval. Data is available; Mn/DOT Office of Freight with its Freight Planning Support System will be able to provide updates. Data is not good for substate and local freight flows Cost is moderate to high (for Global insight data); commitment of staff by Mn/DOT will be helpful.

The project report contains numerous snapshot assessments of performance measures, presented by category (for example, access, safety, network/infrastructure), as well as measurement sources.

- Maintaining and improving databases related to interregional corridors, connectors, intermodal facilities, bridges and pavements
- Compiling and analyzing data from freight studies and various government agencies
- Conducting periodic freight flow studies
- Meeting regularly with a freight advisory group of Minnesota stakeholders to identify freight problems
- Establishing innovative practices to address the availability of freight data, including partnerships between public and private agencies, inter- and intra-agency arrangements, surveys of freight stakeholders and facilities, modeling urban freight movement, and the study of travel time and reliability data
- Monitoring industry data sources
- Investigators recommended developing the following measures in more detail:
- Modal cost of agricultural shipments by markets
- Shipment rates for agricultural shipments
- Transportation cost as a percent of total cost for timber and lumber industry
- Door-to-door time for manufacturing shipments, especially in last leg of supply chain
- Transportation cost for wholesale by market
- Truck parking shortages along corridors or near major shipment, distribution or intermodal centers

What's Next?

Mn/DOT will continue to redefine performance measures and indicators by working with the Freight Advisory Group, government agencies and the private sector to tie measures to the strategic objectives of statewide transportation and freight plans and to identify significant freight corridors and nodes. In the short term, they plan to develop performance measures related to network and infrastructure, safety, travel time and external factors. In the medium term, they will develop access, capacity and reliabilityrelated performance measures. Long-term plans include surveying shippers on a continuing basis concerning inbound and outbound freight movements.

This Technical Summary pertains to Report 2008-12, "Measurement Sources for Freight Performance Measures and Indicators," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200812.pdf.



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Principal Investigator: Stacey L. Stark, University of Minnesota-Duluth





0 12.5 25 50 75

Researchers tested the new toolbox on two ecological subsections: Big Woods and Coteau Moraines.

Improving the Predictive Accuracy of Mn/Model: Modeling Historic and Prehistoric Surface Water Features

What Was the Need?

Mn/Model, an archaeological predictive model developed by Mn/DOT in the late 1990s, applies spatial analysis over large areas to determine the probability of finding precontact archaeological sites and to assess the need for archaeological surveys. The model is used for Section 106 reviews of Mn/DOT projects, helping to decide which areas to avoid and which to survey, as well as providing valuable information for survey design. It also helps Mn/DOT to avoid impacts on archaeological sites and to save money on unnecessary surveys.

Researchers noted that while Mn/Model has worked well using modern lake, river and wetland location information, its analyses have for the most part left out historic and prehistoric surface water features. Modern water features are in some cases the result of human impacts on the land-scape; many historic lakes and wetlands, for instance, have been drained. Abandoned channels represent historic or prehistoric drainage patterns.

Given the significance of water features in predicting the location of archaeological sites, information on historic and prehistoric water features can greatly improve Mn/Model's predictive accuracy, particularly in parts of Minnesota where water features have changed dramatically over the past 10,000 years.

What Was Our Goal?

The goal of this study was to develop a method for mapping historic and prehistoric surface water features from readily available geographic information system data and test it on two Ecological Classification System subsections of Minnesota. Further, investigators aimed to create an automated tool that can be used to model historic and prehistoric surface water features in other parts of the state.

What Did We Do?

First, researchers identified appropriate data sources and developed a methodology to model nowabsent water features. Soils are excellent indicators of past wet environments, particularly in areas that have been artificially drained; county soils data sets (Soil Survey Geographic data from the Natural Resources Conservation Service) were used as the primary input. Additional inputs came from the National Wetlands Inventory; Minnesota Department of Natural Resources surface water features; General Land Office surveyor's plat maps; and high-resolution landform sediment assemblage data, where available, that was developed for Mn/Model.

For the purposes of this study, modern water features are those found in NWI and Mn/DNR data; historic surface water features were defined as modeled water features found on GLO survey plat maps; and prehistoric surface water features were defined as any modeled water feature not recorded in GLO or modern data.

In the second phase of the project, researchers tested their new model on the Big Woods ecological subsection of Minnesota. They then analyzed another subsection, Coteau Moraines, to refine the model for use in other areas.

Finally, researchers automated the model to generate a GIS surface water features layer that reflects historic and prehistoric water features. This was implemented in ESRI ArcInfo 9.2 (ESRI 2005) and built using ArcGIS ModelBuilder.
"The new Historic Water Features Tools make Mn/Model more accurate by identifying locations of water bodies, such as drained lakes, that are not present in modern hydrographic data."

-Elizabeth Hobbs,

State Program Administrator Coordinator/ Geographer, Cultural Resources Unit, Mn/DOT Office of Environmental Services

"We expect that the Historic Water Features Tools, used together with the results of Mn/Model analyses, will greatly improve planners' confidence in their predesign reviews."

-Stacey L. Stark, Director, University of Minnesota-Duluth Geographic Information Sciences Laboratory

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This GIS layer image, generated by the developed toolbox, is overlaid with the Hennepin Conservation District's restorable wetland inventory for Hennepin County. The new tool captured almost all of the HCD wetlands.

What Did We Learn?

Researchers created the ArcGIS Toolbox Historic Water Features Tools, a collection of four tools that together produce a new GIS layer of historic and prehistoric hydrography. Designed to be applied one county at a time, the new tools remove modern water features that are the result of human activities from the input data, and add historic and prehistoric water features. Each tool creates a GIS layer (a shapefile) that can be used separately or with the outputs from the other tools. The new toolbox includes:

- **Tool 1:** Identifies modern, historic and prehistoric lake, wetland and riverine features from soils data.
- **Tool 2:** Identifies the presence of GLO-surveyed lakes that appear as the output of Tool 1; Tool 2 is used only if GLO-surveyed lakes have been digitized.
- **Tool 3:** Adds water features from NWI data, removing artificial features; and incorporates data from the Restorable Depressional Wetland Inventory when it is available.
- **Tool 4:** Combines the output created from tools 1 through 3 with additional data from landform sediment assemblages, where available, to create one shapefile of potential historic and prehistoric water features.

What's Next?

Mn/DOT plans further refinements to heighten the predictive value of the Historic Water Features Tools so that its results are more informative about the nature of the historic and prehistoric water features identified in the tools' output. Future plans also include the use of the hydrographic models in lieu of modern hydrography for improving Mn/Model's ability to predict the presence or absence of archaeological resources.

The toolbox and the reformatted soils data that serves as its primary input are available for use by other state agencies; please contact <u>mnmodel@dot.state.mn.us</u> for more information.

This Technical Summary pertains to Report 2008-13, "Methods to Incorporate Historic Surface Hydrology Layer in Mn/Model [Phase 4] Using Existing Geographic Information System Data," published May 2008. The full report can be accessed at http://www.lrrb.org/PDF/200813.pdf.



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> **PROJECT COST:** \$167,886



This intersection at SR-371 and CR77/49 was monitored during peak time for turn lane queue length and traffic conditions.

How to Determine Optimal Turn Lane Lengths

What Was the Need?

A key task in designing roads is determining the optimal length for turn lanes at busy intersections. Mn/DOT designers typically rely on a combination of engineering judgment and the <u>Mn/DOT Road Design Manual</u> for guidance in performing the necessary calculations. While this approach has produced many successful projects through the years, designers now recognize a need to update the manual. Specifically, better guidance is needed regarding the variables that must be considered when calculating optimal turn lane lengths, such as traffic speed, traffic volume and heavy vehicle mixture.

It may be possible to economize turn lane construction, improve turn lane and intersection safety, and reduce travel delays and emissions in urban roadway networks by optimizing turn lane lengths based on these variables and additional parameters such as deceleration rates, vehicle classes, traffic behavior parameters, land availability, level of service and signal timing.

One difficulty in determining the optimal length of a turn lane, or, specifically, the storage bay portion of the lane where cars queue up while waiting to turn, is accurately predicting the expected queue length given the characteristics of the intersection and the traffic.

What Was Our Goal?

One goal of this study was to validate and quantify the influence of eight variables on turn lane operation that were of particular interest to Mn/DOT designers: speed, through volume, opposing volume, turning volume, crossing volume, heavy vehicle through percent, heavy vehicle turning percent and grade.

Another objective was to develop tools for Mn/DOT that can factor in these variables to accurately predict the length of the turn queue at standard types of intersections.

What Did We Do?

A key task for researchers was to develop tools for predicting the 95th percentile turn queue length, which has a 95 percent probability of not overflowing onto the main line during peak hours. This was posited as the target length for a turn lane's storage bay.

Researchers and Mn/DOT selected 10 intersections for study in the Minneapolis-St. Paul area and rural Minnesota that exhibited a variety of variables believed to influence turn lane operation. Researchers documented each intersection, then analyzed one hour of peak time traffic data from their video footage that included queue lengths and variables such as traffic volumes and number of heavy vehicles on through lanes and on left and right turn lanes. They computed average, 95th percentile and maximum queue lengths in two-minute intervals for all left and right turns. This data was tabulated and used to build computer models of each intersection that emulated traffic conditions.

Researchers then performed more than 14,000 simulations on the computer models to determine the mean value of the average, maximum and 95th percentile queue lengths for each intersection. The parameters used were combinations of the eight variables of interest to Mn/DOT designers. All data was tabulated, and researchers used a standard technique called multivariate regression analysis to assess the influence of each variable on queue length. Regression models were generated on the modeled intersections that predicted the average queue length for each turn lane with a high level of accuracy.

"Data from this study will improve our ability to determine optimal turn lane length under differing types of conditions."

-Glen Ellis, Mn/DOT Metro District Design Engineer

"This research provides the practitioner with simple equations for solving the complicated problem of determining optimal turn lane length."

-Thomas Schnell, Associate Professor, University of Iowa Department of Industrial Engineering

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- d1 = distance traveled during perception reaction time
- d2 = distance traveled while driver decelerates and maneuvers laterally
- da = distance traveled during full deceleration and coming to a stop or to a speed
- at which the turn can be comfortably executed
- d₄ = storage length

This diagram from the *Traffic Engineering Handbook* shows the parts of a right turn lane that a designer must consider: Not only must the storage bay where cars wait be long enough, but cars must have enough time to decelerate into it.

Based on the results of their analysis, researchers developed two toolkits of user-friendly equations for Mn/DOT designers. One calculates average queue length for 14 types of single-lane turns at two-lane and four-lane intersections. The other calculates the 95th percentile queue length (the target storage bay length) for seven types of single-lane turns at two-lane intersections.

What Did We Learn?

This study quantified the level of influence that several variables have on turn lane operation, and researchers used these to develop equations that should be helpful for future turn lane design.

The most significant factors were through volume, opposing volume (for left turns), crossing volume (for right turns), left and right turn volumes, heavy vehicle turn percent for left and right turns, and speed. Heavy vehicle through volume was not found to have a significant impact on turn lane operation, and no through volume appeared to significantly impact turn lane operation for free right turns at unsignalized intersections. The street's grade factor likewise did not appear to affect the left and right turn queue length.

What's Next?

The project technical advisory panel performed a preliminary review of the study results and will next determine how Mn/DOT can best use the project report and what specific implementation steps are warranted. The goal will be to integrate the insights of this study into the *Mn/DOT Road Design Manual* to make it as easy as possible for design personnel to compute turn lane lengths at particular intersections.

This Technical Summary pertains to Report 2008-14, "Turn Lane Lengths for Various Speed Roads and Evaluation of Determining Criteria," published May 2008. The full report can be accessed at http://www.lrrb.org/PDF/200814.pdf.



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Principal Investigator: Gary Davis, University of Minnesota

PROJECT COST: \$55,000



Statistical analysis revealed a number of locations where cable median barriers will improve safety.

Predicting the Cost-Effectiveness of Highway Median Barriers

What Was the Need?

Cross median crashes occur on divided highways when a vehicle leaves the road, crosses the median and collides with a vehicle in the opposing lanes. Between 2001 and 2005, cross median crashes and head-on crashes in Minnesota took more than 600 lives. The <u>Minnesota Strategic Highway Safety Plan</u> targets these crashes for reduction, and Mn/DOT has begun installing median barriers, primarily cable guardrail, in strategic locations around the state as a cross median crash countermeasure.

The results of this initiative are encouraging: Preliminary data indicates that no fatal cross median crashes have occurred on the treated highway sections since installation began in 2004. However, the cost to install the guardrail (\$100,000 per mile) at all desirable locations exceeds available funds. Mn/DOT traffic engineers need methods for identifying sections at greatest risk for cross median crashes and predicting the benefits of installing barriers.

What Was Our Goal?

The objective of this study was to provide Mn/DOT with tools for identifying highway sections at high risk for cross median crashes and for estimating and comparing the costs and benefits of installing barriers on various sections.

What Did We Do?

Researchers created statistical models to estimate cross median crash frequency on different highway sections and identify possible high-risk locations. They also created a simulation model that Mn/DOT could use to predict and compare the cost-effectiveness of cable guardrail projects.

• **Statistical Models.** Researchers used Mn/DOT's computerized crash, roadway and traffic data from Mn/DOT's Highway Safety Information System to build a database for statistical analysis of cross median crashes occurring on urban and rural freeways from 2001 through 2005. Because these electronic records do not explicitly identify cross median crashes, researchers faced the prospect of manually reviewing hard copy accident reports to verify whether crashes in their database were cross median crashes.

To negotiate this problem, researchers developed an analytical technique that used subsets of Mn/DOT's hard copy accident reports to determine which crash records in the database were likely to be cross median crashes. They selected these records for 2003 through 2005 and used them to prepare data files suitable for statistical analyses to identify highway sections at high risk for cross median crashes. Two statistical models were created for these analyses: one for freeways and one for rural expressways.

• Simulation Model. Researchers defined the cost-effectiveness of a proposed barrier project as the project cost divided by the estimated number of cross median crashes blocked by the barrier over a specified number of years. They developed a simulation model that could perform this calculation for a given highway section. The model is Excel-based with a spreadsheet for inputting data such as cross section specifications, average daily traffic count, barrier cost per mile and number of years the estimate should cover. Several data inputs are defaults. The heart of the model is an equation that works with the spreadsheet data to compute and display crash probabilities for the section and the total dollars that could be saved over the estimated period by preventing all cross median crashes.

"This study provided tools to identify where most cross median crashes appear to occur and the cost benefit of installing barriers."

-David Engstrom,

State Traffic Safety Engineer, Mn/DOT Office of Traffic, Safety and Technology

"There were wellestablished statistical tools for screening locations for the risk of relatively frequent types of crashes, such as those occurring at urban and suburban intersections. Median-crossing crashes appeared to have fallen through the cracks."

-Gary Davis, University of Minnesota Department of Civil Engineering

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Cost Effectiveness of Median Barrier Treatments					version:	1.4					
Gary A. Davis University of Minnesota			2 opposing v	ehicles/lane	•						
										opposing	traffic
Cross Section Data:										mean	st.dev
G	d	mu	nsec=	7		ADT=	40000		v	65	5
-0.0417	10.0000	0.7500	edge=	5		Length=	1		tp	1.1	0.25
-0.1667	18.0000	0.4000	nlane_op=	2		Horizon=	10		a	0.65	0.1
0.0000	4.0000	0.4000							veh/l/mi=	12.82	12.82051
0.1667	18.0000	0.4000				ybar=	411.856			enter	compute
0.0417	10.0000	0.7500				vybar=	95.333				
0.0150	12.0000	0.7500				tpbar=	1.100				
-0.0150	12.0000	0.7500				aybar=	20.930	medwid=	60		
			Simulation	n Specs		MVMT=	14.600				
			delta=	0.02		enc/yr=	4.492				
			niter=	15000		memid=	6571	pmid=	0.438067	Exmid=	1.967946
			nsteps=	500		mccrash=	571	pcrash=	0.038067	Excrash=	0.171009
			close2=	4.50		mccross=	1707	pcross=	0.1138	Excross=	0.511229
			nveh=	2							
						\$/mile=	100000				
						cost=	100000			\$/crash=	29238.3

The simulation model uses an Excel spreadsheet to compute the costs and benefits of installing a median barrier based on cross section data, average daily traffic, and other user and default inputs. The example above predicts a benefit (\$/crash) of more than \$29,000 over 10 years for a hypothetical roadway segment.

What Did We Learn?

Researchers used the statistical models to investigate cross median crash risk at 1,443 Minnesota freeway and rural expressway sections. The models estimated cross median crash frequency on these sections for 2003 through 2005, and identified 181 freeway and 80 rural expressway sections where the crash number exceeded zero. The estimated crash number was one or greater for 31 sections and two or greater for four sections. These results were tabulated in the final report along with the estimated number of crashes per mile for each section and the probability that its crash rate exceeds the mean average for all sections in its group.

What's Next?

The software developed for the simulation model was delivered to Mn/DOT with user documentation, and training sessions were conducted for traffic engineers at the Central and District 3 offices. The Mn/DOT Office of Traffic, Safety and Technology intends to use the results of the study to help prioritize cross median crash countermeasures, primarily cable guardrail, for various highway sections, and will use the tabulated results of the statistical analyses to screen for sections that appear to be at risk for cross median crashes. The office also anticipates using the simulation model in the future: The model's spreadsheet requires the user to input cross section data, and that data is not yet readily available for the sections identified in the statistical analyses. Researchers believe that the results of the study will also prove useful to county and local engineers tasked with preventing cross median crashes.





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Principal Investigator: Jonathan Chaplin, University of Minnesota

PROJECT COST: \$146,000



Hand-collecting trash along highways in the Twin Cities area costs more than \$2 million per year.

Designing a Machine for Picking Up Litter Along Minnesota Highways

What Was the Need?

Collecting trash by hand along grassy highway shoulders and medians in the Twin Cities metropolitan area costs about \$2 million per year. "Harvesting" trash in this manner is a time-consuming task that also presents serious safety hazards for Mn/DOT workers. Although there are machines that can remove trash from flat, smooth, paved surfaces, none have been designed to pick up litter from grassy areas or slopes without removing grass or clippings. Designing an off-road trash harvester would make the process of picking up trash easier, safer, faster and more cost-effective. In addition, fewer employees would be needed for trash pickup, freeing up some of them for other assignments.

By 2006, Mn/DOT had completed Phase I of a project to develop an automated alternative. Investigators researched existing machines, technologies and components, and developed an initial set of machine specifications, including dimensions, operational speed and stability.

What Was Our Goal?

The objective of this research was to complete the project already begun to mechanize the trash-collection process by finishing the design and building a prototype of an off-road machine that was easily maneuvered and could pick up most kinds of trash from grassy rights of way, including hillsides, with minimal removal of grass.

What Did We Do?

With the completion of Phase I of the study, Mn/DOT had decided the trash-harvesting machine would be designed to pick up the most common types of trash, including paper, aluminum cans and plastic bottles, plastic, tire parts, and automotive debris such as mufflers and hubcaps.

To begin, investigators developed a computer-aided design model of the full-scale harvester to optimize each of the individual components. Mechanical features that were evaluated and tested in both short and tall grass included a hay rake, time system and vacuum system. The trash harvester was also designed to be capable of sweeping with a capacity of 3.5 acres per hour.

Investigators determined that a shredder-and-blower system was too hazardous for the operator. Instead, a conveyor system was selected for moving the trash to the storage unit at the back of the machine. A Holden tractor is the core of the harvester and provides the hydraulic power; its robust, articulated frame provides a very tight turning radius. The frame of the pickup unit at the front end of the machine was constructed from regular carbon steel tubes; different sections and wall thicknesses were used to make it strong but light. Where needed, cross braces and thicker material were added to further improve the rigidity and integrity of the frame.

In the final prototype, the pickup unit lifts and collects the trash using a combination of tines and a rotary broom. Brushes and tines mounted on a reel push the trash onto a conveyor belt, which dumps it in the storage unit at the back of the machine. Investigators field-tested the unit on unmown meadow grass at a farm.

"With additional modifications, the trash harvester will be a safer and more cost-effective way to keep Minnesota highways clean."

-Jonathan Chaplin,

Associate Professor, University of Minnesota Department of Bioproducts and Biosystems Engineering

"We hope the trash harvester will be improved to the point where it eventually becomes a standard piece of Mn/DOT equipment."

-Sue Lodahl, Director, Mn/DOT Research Services Section

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The trash-harvester prototype developed for this study has a Holden tractor for its core. The front pickup unit lowers onto the tines to scoop up litter and sweep it to a conveyor belt on the right side.

What Did We Learn?

Although the initial field tests were very promising, the prototype did not fully meet Mn/DOT expectations. It did not collect 100 percent of the paper, bottles and soda cans in its path. Considerable trash, especially aluminum cans, became stuck between the lifting tines. At other times, the trash harvester pushed some of the litter to the sides instead of pulling it into the machine.

The investigators provided recommendations for future models:

- The trash harvester's multiaxis, three-point hitch, which was designed to allow fine adjustments to the lifting mechanism, is probably more complex than needed for this type of machine and could be simplified.
- Another potential design improvement would be an automated control system for adjusting the height of the lifters.
- In the prototype, the forward visibility of the operator is restricted by the shield around the rotating tines; this component could be redesigned. The shielding, however, is necessary to prevent bystanders from becoming entangled in the gathering unit.
- The size of the dump bin on the back of the harvester was limited by the position of the conveyor and perhaps could be enlarged in a future design.

What's Next?

Because of mixed test results in the field, Mn/DOT has decided not to commercialize this particular trash-harvester prototype. This initial project has, however, provided a solid base from which to perform additional research, design and testing as funding permits.

Mn/DOT officials hope to implement the investigators' design recommendations and further improve and field-test the trash harvester to enable its standard use. Ideally, redesigns on the harvester will enable it to also perform other roadside land-management operations such as mowing and reseeding.

This Technical Summary pertains to Report 2008-21, "Development of a Trash Harvester for MnDOT—Phase II," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200821.pdf. The report on Phase I of this research is available at http://www.lrrb.org/PDF/200611.pdf.



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PROJECT COST: \$60,000



IC is best used with quality assurance measurement technologies such as LWDs that are quicker and safer than traditional methods.

Putting Research into Practice: Intelligent Compaction Implementation—Research Assessment

What Was the Need?

For a road to perform well over the long term, its subgrade and base layers need to provide a stable, uniform foundation for the pavement. This is achieved by compacting underlying layers (typically with a roller) and performing inspections to ensure that compaction is sufficient.

Compaction can be expensive and labor-intensive, and variability in the consistency of aggregate layer materials makes it difficult to achieve high-quality compaction with uniformity over a large area. Traditional inspection methods such as sand cone testing are inefficient, compromise inspector safety and do not adequately predict performance.

Mn/DOT has invested significant resources to develop alternative procedures using lightweight deflectometers and intelligent compaction. IC involves the use of rollers equipped with sensors that continuously measure subgrade stiffness and can automatically adjust compaction force accordingly. IC improves compaction uniformity and quality, increases compaction efficiency and safety, and consequently saves money on roadway construction and maintenance costs. IC rollers are also equipped with global positioning systems that map the location, time and quality of compaction over the entire surface of each layer. This data is stored for future use in forensic analysis, long-term pavement management and mechanistic pavement design.

Because IC is still a new technology, Mn/DOT and some counties have been performing pilot projects to further develop preliminary IC specifications.

What Was Our Goal?

The objectives of this implementation effort were to qualitatively assess and recommend improvements to Mn/DOT's pilot IC and LWD quality compaction specifications.

What Did We Implement?

This project leveraged previous Mn/DOT work on IC and deflectometer procedures and specifications:

- "Enhancements and Verification Tests for Portable Deflectometers" (2003-10)
- "Validation of DCP and LWD Moisture Specifications for Granular Materials" (2006-20)
- "Moisture Effects on PVD and DCP Measurements" (2006-26)
- "Field Validation of Intelligent Compaction Monitoring Technology for Unbound Materials" (2007-10)
- "<u>Resilient Modulus Development of Aggregate Base and Subbase Containing Recycled</u> <u>Bituminous and Concrete for 2002 Design Guide and Mn/Pave Pavement Design</u>" (2007-25) (A <u>technical summary</u> was produced for this report.)
- "Development of Improved Test Rolling Methods for Roadway Embankment Construction" (2008-08) (A technical summary was produced for this report.)

How Did We Do It?

Investigators synthesized information from literature about LWDs and IC along with Mn/DOT's current IC specifications. They used this information to develop a strategy for conducting interviews with field personnel at four Minnesota sites. Investigators then

"Mn/DOT is on the forefront of intelligent compaction research, and this implementation will be an important resource for other state DOTs that are also exploring more efficient compaction technologies."

-Rebecca Embacher, Mn/DOT Assistant Grading and Base Engineer

"IC has the potential to significantly reduce highway construction costs by improving the quality and efficiency of compaction of subgrade materials."

-Joseph F. Labuz, Professor, University of Minnesota Department of Civil Engineering

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IC rollers include accelerometers mounted on their drums to monitor vibration amplitudes and frequencies. An on-board electronic display system exhibits a colorcoded map of stiffness data analyzed in real time to identify weak areas under the soil.

visited these sites to document activities, review selected records and conduct anonymous interviews with Mn/DOT staff and contractors. Finally, investigators analyzed field data to develop a report recommending changes to LWD and IC procedures.

What Was the Impact?

Recommendations to add to LWD and IC specifications and procedures included:

- Continue to promote LWDs for quality assurance of stiffness. LWDs are portable, efficient and accurate.
- Establish a procedure to determine the target LWD value.
- Eliminate calibration areas (control strips). A procedure needs to be established to determine IC target values to use for varying soil conditions.
- Simplify IC data evaluation and presentation. IC generates a significant amount of data; processing needs to be streamlined to facilitate real-time decision making.
- Calibrate the IC roller and related transducers. A calibration device should be developed to validate the measurements recorded by IC rollers.
- Support development of alternative IC methodologies. Instrumented test rollers equipped with a technology for continuous measurement of rut depths could provide complementary data.

What's Next?

This project relates to a larger, ongoing Mn/DOT effort to implement IC and LWD technology to ensure that roads are built with the greatest efficiency, quality and cost-effectiveness. As part of the next steps in this project, Mn/DOT is currently involved in outreach to inform local agencies, contractors and consultants; these efforts will include a one-day workshop with the construction industry to outline and receive feedback about Mn/DOT's plans for IC. A second workshop will be organized to better educate designers on how IC and LWD technology will influence pavement design.

This Technical Summary pertains to Report 2008-22, "Intelligent Compaction Implementation: Research Assessment," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200822.pdf.

The research being implemented via this project can be found in the six Mn/DOT reports referenced in "What Did We Implement?" These can be accessed at http://www.lrrb.org/PDF/200310.pdf, http://www.lrrb.org/PDF/200620.pdf, http://www.lrrb.org/PDF/200626.pdf, http://www.lrrb.org/ PDF/200710.pdf, http://www.lrrb.org/PDF/200725.pdf and http://www.lrrb.org/PDF/200808.pdf.



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PROJECT COST: \$79,493



Two-inch lengths of steel reinforcement bar were used as frost pins to measure how far frost heave elevates pavement surfaces.



Effects of Seasonal Changes on Ride Quality at MnROAD

What Was the Need?

During the winter, soil under a roadway that has been saturated with water freezes and expands, causing the road to rise. When this occurs unevenly, the result is rougher roads during the winter and spring, and in some cases, cracked pavement surface layers. This problem of "frost heave" is very common in Minnesota, especially on lower volume roads, and can cause serious damage to concrete, asphalt and gravel pavements. It presents one of the greatest challenges to engineers to keep Minnesota's 130,000 miles of roads well maintained throughout the year. Cracked and heaved pavements lead to a bumpy or otherwise poor driving experience for motorists.

Engineers typically respond to these problems with "rough road" signs in the spring, but in extreme cases, roads may require spot grinding, localized overlays or replacement of pavement and underlying materials. These maintenance responses can be costly. While engineers have reduced the occurrence of frost heave over the last 30 years with more blending of lower-lying materials, little is known about the mechanisms involved.

What Was Our Goal?

The objective of this study was to identify how different pavement designs are affected by frost heave and how this relates to ride quality during different seasons. This information will help engineers design pavements to better withstand seasonal variations.

What Did We Do?

Researchers investigated frost heave by gathering and analyzing related data and correlating it to pavement characteristics and ride quality. Much of this data was from MnROAD test cells constructed in the early 1990s, collected as part of normal operating procedures at the time.

First, they selected 20 pavement sections at the MnROAD research facility—eight constructed with portland cement concrete and 12 with hot-mix asphalt. They then installed frost pins—2-inch-long pieces of rebar—into the pavement sections flush with the surface and surveyed periodically through the seasons to determine the heights of the pins over a four-year period. Mn/DOT's pavement management vans were driven over MnROAD test cells at different times of the year to measure ride quality.

Researchers then evaluated this heave and ride data to determine:

- How different mix designs (HMA, PCC, base types and thicknesses, subgrade type) affect the total (maximum), duration and consistency of frost heave throughout the year
- How the frost measured for the MnROAD test cell designs correlates to the measured ride roughness

What Did We Learn?

Design Features. Investigators found that:

- For concrete, a longer design life has no significant impact on frost heave performance, but design life correlates with better resistance to frost heave in asphalt.
- Clay subgrades experience more frost heave than sand subgrades under both concrete and asphalt.
- Better drainage results in less frost heave for both concrete and asphalt.
- For both concrete and asphalt, thick pavements bear heavier loads and often extend the pavement structure down to the level that frost penetrates the soil, reducing frost heave. A thicker pavement even mitigates the impact of nonuniform frost heave.

"We found essentially that pavements over a sand subgrade, thicker pavement structures and pavements with drainable bases exhibit less frost heave than other pavements."

-Lev Khazanovich,

Principal, Associate Professor, University of Minnesota Department of Civil Engineering

"This study confirmed our current practices in responding to frost heave, but didn't provide enough input to change our design specifications. Improving data collection and ride analysis methods may offer more insight."

-Benjamin Worel, MnROAD Operations Engineer, Mn/DOT Office of Materials

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Damp subgrade and pavement may shift during expansion in freezing temperatures, causing frost heave that can severely damage surface conditions and ride quality.

- Asphalt binder types do not affect frost heave performance.
- In asphalt designs, coarser base materials hold less water and so suffer less frost damage.
- In concrete, joint spacing does not affect overall frost heave magnitude, but frost heave damage is more concentrated in short-spaced slabs, which have smaller areas for the distribution of heave stress.

Ride Quality. While investigators could not confirm a correlation between frost heave and ride quality deterioration on flexible pavements, they did not reject the hypothesis that frost heave degrades ride on rigid pavements insofar as thicker concrete pavements experience less frost heave damage.

Seasonal Variations. Frost pin elevations begin to increase at the end of September and reach their highest points in early March, then decrease until mid-April. From May to September, frost pin elevations change very little. Though ride quality improves in summer months, no seasonal statistical connection was established between pin heights and ride quality.

What's Next?

Investigators suggest that a refined approach to ride quality data collection and assessment methods might offer better data on any correlation between ride quality and frost heave magnitude.

Since thicker MnROAD test cells exhibited less frost heave, which was correlated with ride quality in concrete pavements, there is also a need for further investigation of the benefits of using thicker bases under concrete pavements.

Investigators recommended other improvements in design and construction practices to improve ride quality, including research into the mix design for HMA pavements to reduce thermal cracking—the main cause of roughness—and steps to improve the initial roughness of concrete pavements.



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Principal Investigator: Amiy Varma, North Dakota State University

> **PROJECT COST:** \$71,000



Researchers captured speed data for building a right-turn crash prediction model.



Traffic Volume Thresholds for Requiring Right Turn Lanes and Treatments on Two-Lane Roads

What Was the Need?

When improving or building intersections or driveways on two-lane state highways, local governments and permit applicants must follow criteria established in Mn/DOT's *Road Design Manual* and *Access Management Manual* for what level of traffic triggers the need for right turn lanes. These criteria set thresholds designed to maintain safety near intersections, business driveways and other locations where the main thoroughfare lacks traffic signals or other forms of traffic control.

The manual's current volume warrants are based on engineering judgment rather than quantitative analysis and include volume thresholds that have not been definitively validated by research. As a consequence, it is unclear if the approach to intersection design used by Mn/DOT and local agencies is as cost-effective, safe or efficient as it could be.

There was a need to re-evaluate these policies through a quantitative study and definitively establish the traffic volume thresholds for requiring right turn lanes and related treatments, such as shoulder widening, on two-lane roads.

What Was Our Goal?

The objective of this study was to analyze geometric, traffic, speed and crash data for two-lane roads in Minnesota at locations where the main thoroughfare lacks traffic signals or other forms of traffic control. This data is needed to provide firm empirical grounding for volume-based warrants for the implementation of right turn lanes and other treatments.

What Did We Do?

Researchers focused their analysis on determining the safety and operational effectiveness of right turn lanes and treatments. For the safety assessment, researchers analyzed Mn/DOT crash data, developed a model capable of predicting crashes of different severities caused by right turns, and computed the cost for crashes involving right-turning vehicles.

The crash data included all reported crashes from 2000 to 2002 and 2004 to 2005 on two-lane roads that involved at least two vehicles, as well as a subset of this data for crashes involving right turns. Researchers combined the results of this analysis with Mn/DOT crash cost data to calculate the average cost for crashes involving exclusive right turn lanes (right turn only) and shared lanes (with traffic turning directly from the through lane). They then collected field data at 24 intersections with exclusive and shared right turn lanes to build a model capable of predicting right-turn-related crashes at these types of intersection.

For the operational assessment, researchers examined the effect of right turn lanes and other treatments on delays to through traffic and consequent fuel consumption. Field data was collected at 13 intersections and used in conjunction with CORSIM traffic simulation software and data from Mn/DOT's Office of Investment Management to develop simulation and regression models that calculated the average delays and fuel consumption at these intersections. Researchers then developed 20 provisional, volume-based right turn lane warrants for intersections and commercial and public driveways; these warrants balanced the cost to construct a right turn lane or treatment with the savings gained from reductions in crashes and operational costs.

"The volume thresholds developed in this project provide Mn/DOT with legally defensible criteria for requiring private developers to establish right turn lanes."

-Brian Gage,

Access Management Engineer, Mn/DOT Office of Investment Management

"The warrants developed for this study are sensitive to right turn lane construction costs and fuel prices—key factors that vary over time and with geographic location."

-Amiy Varma,

Associate Professor, North Dakota State University Department of Civil Engineering

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Researchers developed 20 provisional right turn lane warrants for intersections and driveways, establishing thresholds for volume and speed of through traffic (DDHV) and right-turning traffic (RT DHV) for various turn-lane construction and fuel costs.

Construction costs were calculated with the assistance of the technical advisory panel, with savings due to safety benefits calculated as the difference between the total annual cost for crashes incurred because of vehicles turning from shared right turn lanes and the cost incurred from exclusive right turn lane crashes.

Crash costs were computed using a crash severity model in conjunction with crash cost data from Mn/DOT. Savings due to operational benefits were determined by subtracting the total annual costs for delays and fuel consumed during delays at locations with shared movements from the same costs at locations with exclusive right-turn movements. Costs were assumed to be \$13 per vehicle for a typical delay, and \$3 or \$4 for a gallon of fuel.

What Did We Learn?

The study data suggested that adding exclusive right turn lanes and treatments at intersections and driveways could lead to crash cost savings at high-volume locations where about 45 percent of vehicles on the main thoroughfare turn right: more than \$10,000 per year at high-speed locations and \$5,000 per year at low-speed locations. At \$4 per gallon, exclusive right turn lanes could also save more than \$25,000 per year in delay and fuel consumption costs at high-volume locations where about 25 percent of mainline vehicles turn right.

Adding exclusive right turn lanes significantly reduced only rear-end crashes; these had a greater effect on safety at commercial entrances and private driveways than at public intersections.

What's Next?

In the coming months, Mn/DOT will hold discussions about incorporating the results of this study into the *Road Design Manual*. These discussions will incorporate the results of other recent projects, including "<u>How to Determine Optimal Turn Lane Lengths</u>" (2008-14).

This Technical Summary pertains to the LRRB-produced Report 2008-25, "Warrants for Right-turn Lanes/Treatments on Two-lane Roads," published July 2008. The full report can be accessed at http://www.lrrb.org/PDF/200825.pdf.



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PROJECT COST: \$25,502



The standard emergency lighting currently used on Mn/DOT snowplows consists of an HID strobe light like the one shown here.

LED Emergency Lighting for Snowplows and Other Maintenance Vehicles

What Was the Need?

Mn/DOT maintenance and construction vehicles are required to have emergency lighting to ensure the safety of workers and motorists. The current standard for Mn/DOT snowplows is high-intensity discharge strobe lighting, or HID.

In an effort to reduce maintenance costs, Mn/DOT is exploring the possibility of replacing HID on snowplows with light-emitting diodes because LED-based strobe lighting is more efficient and reliable than HID lighting. However, observation suggests that under certain conditions and from certain angles, LED lighting is less visible than standard HID lighting and so may not be as safe. Further, very little data is available about the effectiveness and safety of using LED lights on snowplows. For Mn/DOT officials to make an informed decision about whether to move to LED lighting on snowplows and other highway maintenance and construction vehicles, they needed to consider the results of comprehensive testing of this new solution.

What Was Our Goal?

The goal of this project was to better understand the effectiveness of LED strobe lights as a replacement for the standard HID strobe lights currently used on Mn/DOT snowplows and to develop a set of specifications for LED-based lighting. This data will allow Mn/DOT to decide whether using LED-based lights on snowplows is a safer alternative, under a variety of conditions, to using the standard HID lighting system.

What Did We Do?

Researchers compared HID and LED lighting technologies using a number of field and laboratory tests, including intensity measurements, optical intensity measurements, visibility testing and light spectrum measurements.

Researchers first performed intensity measurements and field tests to determine the correlation between the optical power output and conspicuity of LED and HID lights. Lab testing included detailed optical measurements of angularity brightness and color. Field tests compared the effectiveness of LED and HID lights, including their perceived brightness at a distance under typical driving conditions.

Researchers then measured optical intensities of LED and HID lights using equipment that enabled semiautomatic intensity measurements at various observation distances and viewing angles typical for drivers. They then conducted visibility testing by recording the minimum distances at which an observer could identify strobes under different weather and driving conditions, including light fog, snow-fog, heavy snow and morning to late-afternoon sun.

Finally, researchers determined color differences in HID and LED strobe lights by taking measurements of the visible light spectrum emitted by them. They also established electrical power output by measuring the DC voltage delivered to the strobes and pulsed current drawn by the lights.

What Did We Learn?

The results of this research suggest that only for some conditions are LED-based lights as conspicuous as the standard HID strobe lights currently used on Mn/DOT snowplows. When viewed from a direction typical of a vehicle approaching the snowplow from the rear, the LED-based lights were just as conspicuous as the standard strobe lights. But

"The research showed that compared with standard HID strobes, the visibility of LED-based strobes is reduced from some viewing angles. More research is needed as to whether these angles affect driver safety."

-Tim Vogt,

Chair, St. Cloud State University Department of Electrical and Computer Engineering

"LED-based strobes should be more cost-effective on snowplows than standard strobes because they last longer and use less current."

-Farideh Amiri,

Maintenance Operations Research Engineer, Mn/DOT Office of Maintenance

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Compared to the standard HID strobe light, LED emergency strobes (above) are not as visible from as many different angles of driver approach, possibly creating safety issues.

because of the strong variation in and correlation between intensity and viewing angle for LED devices, they were less visible than standard HID strobes when approached from a variety of other angles.

Because LED- and HID-based lights were shown to be equally visible under some conditions, it is necessary to determine those conditions that are relevant to safety and effectiveness, and those that are not. With respect to good visibility for vehicles approaching the rear of a snowplow under typical conditions, LED-based systems are probably as effective as HID-based lights as well as being less costly.

What's Next?

By replacing standard HID with LED strobe lights on snowplows and other maintenance and construction vehicles, Mn/DOT could save a considerable amount in maintenance and energy costs. While this study did not show LED lights to be as safe as HID lights in all conditions, it constitutes a first step in analyzing the most significant factor affecting the visibility of LED-based lights: the angle of approach.

LED technology is rapidly evolving, and it would be useful to test the next generation of LED lights for snowplows and other maintenance and construction vehicles. This research should include a more detailed analysis of how the parameters of LED-based lighting systems—intensity, angle, color, timing and power—can be controlled to design LED lenses that automatically correct the angularity problems identified in this study.



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> PROJECT COST: \$50,000



Do bicycle facilities like this one being constructed in Minneapolis increase the percentage of people who commute by bicycle?

The Impact of Bicycling Facilities on Bicycle Commuting Levels

What Was the Need?

Since the 1990s, interest in multimodal travel has increased significantly. In 1991, Congress passed the Intermodal Surface Transportation Efficiency Act, and in 1994, the Federal Highway Administration made doubling the percentage of trips made by foot or bicycle a federal goal.

One approach to meeting this goal has been to provide alternative transportation facilities to urban commuters by building off-street bicycle trails and creating designated bicycle lanes on city streets. Because these infrastructure projects generally require considerable political and economic investments, evaluating their effectiveness has been an important priority for Mn/DOT.

In 2005, Mn/DOT published <u>a study examining how the addition of bicycling facilities</u> <u>during the 1990s influenced bicycle commuting rates in the Twin Cities</u>. This study showed that new facilities were correlated with a small but statistically significant and consistent increase in bicycle commuting rates for areas immediately surrounding these facilities. More research was needed to determine if these results could be confirmed by studying other cities that experienced comparable new facility construction.

What Was Our Goal?

The purpose of this study was to determine whether the presence of new bicycle facilities could be correlated with an increase in bicycle commuting rates in various U.S. cities, replicating the results of the 2005 Twin Cities study. Investigators also sought to identify contextual factors that help explain why bicycling facilities are more effective in some locations than others.

What Did We Do?

Investigators used the same methodology as the 2005 Twin Cities study to evaluate six other cities that constructed new facilities in the 1990s: Austin, Texas; Chicago; Colorado Springs, Colorado; Salt Lake City; Madison, Wisconsin; and Orlando, Florida. These cities were chosen because they had new bicycle facilities, official bicycle planning agencies and up-to-date maps of facilities.

Researchers began by cooperating with local bicycle coordinators in these cities to map off- and on-street bicycle facilities that were constructed in the 1990s, were at least a mile in length and improved accessibility to employment destinations.

Investigators then determined the change in bicycle commute rates for locations within a certain distance of these facilities: They identified Bicycle Analysis Zones for each city consisting of U.S. Census block groups with geographic centers falling within 2.5 kilometers of a relevant facility. They then collected and compared 1990 and 2000 census data for block groups within each city's zones.

Finally, they conducted interviews with city bicycle coordinators to provide context for these results, focusing on how factors such as political culture, housing density, employment patterns and publicity efforts may have influenced the success of bicycle facilities.

What Did We Learn?

Despite the Twin Cities' success, results did not show that new facilities have a standalone effect on bicycle commuting rates. While Austin and Chicago experienced a "The value of the first Twin Cities study was developing the methodology. The value of this study was learning if the findings hold true in other locations and developing additional sociological methodologies to explain why."

-Darryl Anderson, State Bicycle and Pedestrian Coordinator, Mn/DOT Office of Transit

"Communities considering adding bicycle facilities should be cognizant of how new facilities will fit into their existing networks and land use plans. It's also important to plan for publicizing and supporting facilities once they are completed."

-Frank Douma,

Assistant Director of the State and Local Policy Program, Hubert H. Humphrey Institute of Public Affairs, University of Minnesota

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For each city, researchers mapped bicycle facilities constructed in the 1990s, and they identified a Bicycle Analysis Zone. Austin and Chicago were the only cities of the six analyzed that experienced statistically significant increases in bicycle commuting within these zones.

statistically significant increase in bicycle commuting, other cities showed either statistically insignificant changes or declines. Contextual factors may play a significant role in determining why bicycle facilities are more effective in some locations than others. Three themes were identified in the interviews with bicycle coordinators in cities where bicycle commuting rates increased:

- Location of facilities along usable commuting routes between residential areas and city employment hubs
- Overall network connectivity, with trails and bicycle lanes covering a large part of the central city and numerous intersections that allow easy navigation from one part of the city to another
- Publicity and promotion, including efforts by city planners and advocates to advertise their presence and promote bicycle commuting among city residents

Demographic profiles of census block groups indicate that locations with the greatest number of bicycle commuters tend to be more densely populated, located in or near the central business district, contain high percentages of individuals who walk to work, have a population with a median age in the early 20s, and have household incomes that are considerably below median incomes for the city as a whole.

What's Next?

The project was presented at the 2008 Annual Transportation Research Conference and raised several questions requiring further study. Research will be needed to determine how bicycle facilities constructed between 2000 and 2010 affect bicycle commuting rates. City policymakers also need quantitative and qualitative methodologies for making decisions about bicycle commuting in their cities. Research currently under way includes a study of bicycle users' travel purposes in Minnesota, which will enhance understanding of off-street facilities and provide an important groundwork for future research into travel behavior, including noncommuter bicycling.

This Technical Summary pertains to Report 2008-33, "The Impact of Bicycling Facilities on Commute Mode Share," published August 2008. The full report can be accessed at http://www.lrrb.org/PDF/200833.pdf.





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Principal Investigator: Bruce Wilson, University of Minnesota

PROJECT COST: \$89,000



The enhanced simulation program accounts for off-site sediment control tools such as detention ponds to help planners design environmentally responsible construction sites.

Design Tool for Controlling Runoff and Sediment from Highway Construction

What Was the Need?

Storm water runoff from construction sites can degrade the quality of waters in streams and lakes. To protect these valuable resources and limit environmental damage, the Minnesota Pollution Control Agency requires that storm water pollution prevention plans be developed for construction activities that disturb areas of 1 or more acres.

Using best management practices to control runoff sediment from highway construction sites is an important component in construction site design. Understanding erosion processes and implementing erosion/sediment BMPs have been the focus of several research studies sponsored by Mn/DOT and the Minnesota Local Road Research Board. One earlier project to improve the usefulness of experimental data entailed developing a risk simulation tool called WATER (Watershed Assessment Tool for Environmental Risk). WATER simulates the impact of highly variable weather conditions on runoff and erosion for a single construction site.

However, the simulation tool proved to have limitations. Most glaring was the omission from the modeling data of widely used off-site sediment runoff control practices such as detention ponds and rock check dams. Without this data, project planners did not have a complete picture of available practices. Equally important, the simulation tool lacked a user-friendly interface for easy, quick analysis of the runoff data.

What Was Our Goal?

The objectives of the project were to significantly enhance the WATER simulation tool by:

- Incorporating the effects of off-site sediment control practices (those practices taking place a mile or more from the construction site)
- Expanding the WATER model to include processes at a watershed scale by linking together the responses of different land uses
- Developing a more user-friendly interface

What Did We Do?

To include off-site data in the modeling equations, the development team expanded the WATER model to include off-site practices like rock check dams, vegetative filters and detention ponds. In addition, the simulation tool was enhanced to accomplish five types of modeling:

- Risk assessment for a single construction site
- Modeling of multiple land uses within a watershed
- Standalone modules to model off-site processes, including rock and gravel infiltration filters
- Calculations from a feedlot runoff
- Application of a statistical tool to analyze environmental problems

The tool's modeling was also expanded to allow flow and sediment from different areas within a watershed to be combined for determining the overall response of the watershed.

"If not controlled, sediment can impede water flow and reduce water quality. The enhanced WATER simulation tool will provide a more scientific way of defining and managing the erosion risks of construction projects so we can minimize the environmental impact."

-Brett Troyer,

Principal Engineer, Mn/DOT Environmental Services

"We've been recording erosion data for awhile, but not in a useful format. Our new simulation program gives construction planners good information that lends itself to real-world applications."

-Bruce Wilson,

Professor, University of Minnesota Department of Biosystems and Agricultural Engineering

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Creating a new project or running a simulation on an existing one is easy with WATER's project wizard, letting project engineers run simulations against their design to help define, test and, if needed, alter BMPs.

The investigators enhanced WATER to allow users to retrieve and edit input data, carry out continuous simulations, view output results graphically and work with GIS layers. Planners can run extensive simulations for extreme weather conditions—which help to define BMPs—as well as run "what-if" circumstances to determine worst-case scenarios.

In addition, to provide more accurate results, two different algorithms were developed for the WATER model to predict the hydraulic response and removal of sediment in rock and gravel filters.

What Did We Learn?

Enhancements to the WATER risk simulation tool were critically important for practitioners and construction planners. These enhancements provide scientific support for construction design plans and help to define BMPs.

Overall, Mn/DOT was very satisfied with the improvements made to WATER. With the inclusion of both on- and off-site factors, construction planners have a better source of information to develop and test plans. This ultimately leads to construction projects with less environmental risk to neighboring water supplies.

Interestingly, the enhanced WATER program will benefit not just construction planners, but other agencies in Minnesota as well. For instance, the Minnesota Pollution Control Agency will look to the WATER tool to help define water quality standards throughout the state.

What's Next?

While WATER was successfully enhanced to provide a better, more complete source of information for construction site planners, improvements are still needed in its usability. Currently, users need extensive knowledge of what data to input and how to input it to obtain accurate, relevant information. Planning is under way for a second phase of this effort, with the goal of creating a simpler, more intuitive user interface.

Mn/DOT Research Services is considering conducting after-the-fact surveys to gauge the degree to which the workshop facilitated changes in practice at the local level.

This Technical Summary pertains to Report 2008-35, "Design Tool for Controlling Runoff and Sediment from Highway Construction," published August 2008. The full report can be accessed at http://www.lrrb.org/PDF/200835.pdf.



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Principal Investigator: Michael Manser, University of Minnesota

PROJECT COST:

\$50,000



Older drivers display an increased crash risk after age 65 years.

Generational Perspective on Teen and Older Drivers on Traffic Safety in Rural and Urban Communities

What Was the Need?

A 2002 National Safety Council report indicates that road traffic injuries are the most common cause of death in the United States for all age groups up to 75 years, with the rate of fatal crashes higher in rural areas. Teen, young adult and senior drivers have the highest fatality rates. Research further indicates that most crashes are the result of driver impairment or high-risk driving behavior.

Why are rural crashes more common? Why are teen and senior drivers experiencing the highest fatality rates? An <u>LRRB-funded study completed in 2007</u> explored this topic through surveys and driving simulator tests, concluding that driver perceptions of risk that fed into high-risk behavior (speeding, nonuse of seat belts, driving while impaired) were correlated with age and residency (rural versus urban). More investigation was needed to further understand these connections in order to tailor effective safety interventions to specific categories of high-risk drivers.

What Was Our Goal?

The goal of the current project was to provide information to further improve the effectiveness of Minnesota traffic safety programs through additional investigation into the experiences and perceptions of teen and senior drivers in rural and urban communities. Specifically, researchers wanted information about:

- Perceptions of crash risk, safe driving practices, driving ability and the importance of personal mobility to quality of life.
- Perceptions of the suitability and effectiveness of various types of safety interventions, such as the current Graduated Driver Licensing program and enforcement campaigns targeted toward specific behaviors (such as driving while impaired) in particular geographic areas.

What Did We Do?

The first phase of the project consisted of a series of 12 focus groups—with 116 participants—to gauge attitudes and experiences on these topics. Participants were from one rural area and one urban area of Minnesota, and were recruited for three subgroups: teen drivers, senior drivers (65 years or older), and parents of teen drivers.

In the second phase of the project, researchers evaluated surveys that were completed by the participants before they attended the focus group. These surveys solicited information about participants' self-reported driving behavior, perceptions of driving risk and the effectiveness of traffic safety interventions. Survey questions were formulated in consultation with the Minnesota Department of Public Safety and officials affiliated with Mn/DOT's Toward Zero Deaths initiative.

What Did We Learn?

Researchers learned that teen and senior drivers from both rural and urban communities rely on driving to preserve their independence and avoid inconveniencing others. While these drivers share a common driving purpose, researchers noted differences with regard to self-reported crash risk:

• Rural residents, regardless of age, reported less frequent use of seat belts.

"This study indicates a difference in perception between age cohorts with regard to crash risk: Distractions were problematic for teens, while senior drivers cited the deterioration of perceptual, cognitive and psychomotor processes."

-Gordy Pehrson,

Traffic Safety/Youth Alcohol Coordinator, Minnesota Office of Traffic Safety

"Teen driver support systems like Smart Technology give teen drivers immediate feedback about driving performance and provide the opportunity to improve teen driver behavior, especially within the first six months to one year of driving."

-Michael Manser,

Director, HumanFIRST Program, ITS Institute, University of Minnesota

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Speed alerts, which use an in-vehicle computer and GPS to warn teen drivers about risky driving speeds, were among the elements of Smart Technology discussed in focus groups.

- Urban drivers reported more frequent driver errors and traffic violations.
- Teens driving in urban environments reported more episodes of aggressive and impaired driving, moving violations and lapses in attention (distraction).
- Seniors attributed crashes to slower reaction times, poorer vision, reduced hearing or other physical problems.

Participants' perceptions of safety interventions also differed, as evidenced by the following:

- Teen drivers were significantly less receptive to enforcement as a safety intervention than senior drivers.
- Teens felt the use of Smart Technology to monitor driving behaviors such as speed and seat belt use could have positive safety effects, but an acceptable program would need to balance factors such as cost, robustness and limitations on driving patterns.
- While most teens felt the current GDL program, which is intended to reduce risk exposure and improve teen driving, had allowed them to improve their driving skills, they were less certain that the GDL program had made them safer. Most teens were against limits on the number of passengers and nighttime driving for newly licensed drivers, citing inconvenience.
- Mobility programs (private, nonprofit community organizations that provide transportation and mobility services to seniors) were better received by seniors in urban areas, provided the programs were convenient, safe, affordable and flexible.
- Seniors were receptive to mandatory driver's license retesting, but felt that it should be convenient, fairly administered and related to driving behavior, not a specific age.

What's Next?

Potential policy recommendations and suggestions for future research arising from this project include targeting traffic safety campaigns in rural areas that encourage seat belt compliance; developing safety policy for teen drivers that addresses driver distraction, especially in urban areas; developing safety policy for senior drivers that focuses on sensory-motor functioning; identifying ways to tailor the GDL program to optimally meet the needs of teens and parents; and investigating the feasibility of implementing mobility systems, especially in rural areas, as well as the barriers to program use and sustainability.

This Technical Summary pertains to Report 2008-36, "Generational Perspective on Teen and Older Drivers on Traffic Safety in Rural and Urban Communities," published September 2008. The full report can be accessed at http://www.lrrb.org/PDF/200836.pdf. The 2007 study that served as a precursor to this study is described in brief at http://www.lrrb.org/PDF/200741TS.pdf; the full report is available at http://www.lrrb.org/PDF/200741.pdf.



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Principal Investigators: Neal Hawkins, Iowa State University Omar Smadi, Iowa State University

PROJECT COST: \$56,802



The mapping tool uses retroreflectivity data collected by Mn/DOT using handheld devices that measure key variables.

Developing and Implementing Enhanced Pavement Marking Management Tools: Phase I—Mapping Tool

What Was the Need?

Pavement markings are an essential component of highway construction and roadway safety. Drivers need to quickly identify where the markings are and what they are telling them. Good pavement markings provide critical elements to guide drivers on correct road paths, supplement road signs to inform and warn drivers, and improve night driving conditions.

The key factor in determining the nighttime visibility of pavement markings is retroreflectivity: their ability to reflect light back to the driver. Retroreflectivity is determined by the type and method of marking (typically paint, epoxy or preformed tape) and how it degrades over time. Tracking this information provides a practical method for maintaining markings, saving money and making roads safer.

The Iowa Department of Transportation had recently completed a statewide implementation of a system to organize its pavement marking data and make it available to field offices and paint crews. Mn/DOT wanted a comparable tool to bring together the separate marking databases maintained by each Mn/DOT district to ensure that decisions regarding pavement marking needs, durability and quality were made consistently, objectively and cost-effectively.

What Was Our Goal?

This project was Phase I of a comprehensive project to better manage Mn/DOT's pavement marking processes and tools, designed to help each Mn/DOT district determine its restriping needs. The objective of Phase I was to create a mapping tool to enable users at many locations to map and query retroreflectivity and marking application production information.

This software needed to quickly and easily provide insight into the quality of pavement markings on the roadway system to enable better-informed maintenance and restriping decisions. The tool needed to employ a platform that required little installation time or technical support.

What Did We Do?

Mn/DOT engaged the Center for Transportation Research and Education at Iowa State University for this project because CTRE had developed Iowa's system. A key task was for CTRE to gain a thorough understanding of Mn/DOT's unique situation and needs. CTRE and Mn/DOT held a series of information-gathering sessions where critical decisions were made, including:

- How to retrieve, sort and analyze data sources needed for display in the mapping tool.
- What data items needed to be included and how to collect them from the available data.
- How to incorporate pavement marking information in the Geographic Information System database used by the mapping tool.
- How to fit the tool into Mn/DOT's system architecture.

These discussions gave CTRE the insight to develop the tool and associated data queries. CTRE provided a report that included an overview and user's manual for the tool, and proposed a recommended course of action for its subsequent refinement.

"The Pavement Marking Management Tool and its initiative is 100 percent in line with Mn/DOT's Strategic Plan: 'Mn/DOT will continuously improve service and efficiency in order to give citizens the best value for their tax dollars by encouraging innovation ... through creative, cost-saving solutions.'"

-Sue Groth,

Director, Minnesota Office of Traffic and Safety

"Based on our initial conversations with Mn/DOT, we were able to build an easy-to-use tool that presented itself to the user as an extension of the Mn/DOT Web site."

–Omar Smadi,

Research Scientist, Center for Transportation Research and Education at Iowa State University

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The tool includes a GIS map showing retroreflectivity across Minnesota roadways, which serves as a visual aid for locating problem areas and planning paint marking strategically. Routes with retroreflectivity data are highlighted by color.

What Did We Learn?

This first phase of the Pavement Marking Management Tool project showed that the previous way of tracking which roads needed pavement marking attention was outdated and could be greatly improved. It also became apparent in the course of this study that pavement marking data needed to be made available not only to central planning locations, but also to district offices and paint-marking teams.

The simplicity and organization of the software validated Mn/DOT's decision to pursue its implementation. It can be accessed via any Web browser, requires no software installation or maintenance by users, populates the database behind the scenes, and provides retroreflectivity values that can streamline planning and improve decision-making for maintenance of pavement markings throughout Minnesota.

What's Next?

The Pavement Marking Management Tool will provide a significant resource to Mn/DOT staff in developing short- and long-term pavement marking plans by offering a tool to research and monitor the performance of its pavement markings, while also determining that performance relative to the cost of that type of marking. To realize the benefits of this tool, Mn/DOT needs to take additional steps, including:

- Providing additional district training and demonstration.
- Establishing standard Oracle data tables.
- Developing retroreflectivity data flow requirements at both central and district offices; for example, to support automated entry of Global Positioning System data from Mn/DOT's paint stripers and from retroreflectivity vans. Mn/DOT should also explore using tools such as GPS-enabled PCs or handhelds to automate data entry in the field from the department's many types of striping equipment.
- Incorporating paint data from both Central Office and Contract Striping, which will give staff the ability to match marking performance with installation information.

Ultimately, CTRE and the Mn/DOT Central Office Pavement Marking Engineer will provide training on the tool to Mn/DOT personnel in each of the eight districts.

This Technical Summary pertains to Report 2008-37, "Developing and Implementing Enhanced Pavement Marking Management Tools for the Minnesota Department of Transportation: Phase I—Mapping Tool," published September 2008. The full report can be accessed at http://www.lrrb.org/PDF/200837.pdf.



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PROJECT COST: \$88,000



Pappi are featherlike tufts that facilitate wind dispersal of Canada thistle seeds.

Production and Wind Dispersal of Canada Thistle Seeds

What Was the Need?

Canada thistle is the most prevalent noxious weed on Minnesota roadside rights of way, and Mn/DOT puts a high priority on controlling its infestations. A non-native and invasive species that can outcompete native plants, Canada thistle is a costly threat to farmlands, natural ecosystems and roadway safety.

Canada thistle is very difficult to manage, in part because of its propagation by windborne seeds. Seeds are facilitated in wind dispersal by loosely attached, featherlike tufts called pappi. Public and private landowners are required by law to control Canada thistle and often assume that windblown seeds are an important means of dispersal and invasion of new sites. It was unclear to what extent this assumption was correct, and whether optimal management practices were in place.

Canada thistle seeds separate easily from pappi, so they may not travel as far as generally thought. Further, seed production by Canada thistle is highly variable: Many flowers do not produce seeds, and seed viability varies greatly. Finally, seeds take flight at a time of year when herbicide use, mowing or hand rouging are minimally effective in controlling the perennial root system. Management practices are expensive and can damage desirable native ecosystems. For these reasons, the land managers' goal is to obtain the best control of the thistle stand, not merely its seed flight. Controlling Canada thistle's extensive underground root system is more economically and effectively achieved in the late spring before flowers set seed or in the fall after seeds are produced.

What Was Our Goal?

The objective of this study was to better understand the role that wind dispersal and seed production play in the spread and persistence of Canada thistle infestations, ensure that Mn/DOT enforcement guidelines for long-term thistle management are cost-effective and address actual rather than perceived problems.

What Did We Do?

Researchers conducted two experiments: The first characterized the extent of Canada thistle wind dispersal, and the second, the quantity and viability of seeds produced by Canada thistle stands.

In the first experiment, researchers used traps constructed of adhesive-coated wire mesh to evaluate the quantity, viability and dispersal distance of windblown seeds and pappi at 12 Minnesota sites during 2006 and 2007. Researchers recorded the number of pappi released and whether or not a seed was attached, and used laboratory tests to evaluate seed viability. They then counted the number of flower clusters in Canada thistle stands and estimated the percentage contribution to dispersal. Finally, researchers mapped seed and pappi deposited at various distances from thistle stands to evaluate the effect of wind on the direction and distance of seed dispersal. In the second experiment, researchers monitored the production and viability of seed in Canada thistle populations at eight Minnesota sites to better characterize typical seed production potential.

What Did We Learn?

Wind dispersal is not as significant a factor in the movement of Canada thistle seeds as was commonly thought. Most viable seeds fall to the ground nearby without pappi attached. Further, many seeds produced by Canada thistle stands are either nonviable or of questionable viability. "There was not a lot of long-distance wind dispersal of seed. Land managers are better off focusing on controlling the seedbanks of Canada thistle patches themselves than on wind-based dispersal."

-Donald Wyse,

Professor, University of Minnesota Department of Agronomy and Plant Genetics

"Adapting management practices to the realities of Canada thistle dispersal could make controlling this weed considerably less costly and more environmentally friendly."

-**Tina Markeson,** Mn/DOT Senior Natural Resource Forestry Specialist

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Many seeds produced by Canada thistle stands are empty (left), without the embryo and starch accumulation of a regular seed, and so cannot germinate. Full seeds (right) are shown for comparison.

Wind strength had relatively little influence on dispersal. Even in the rare case of sustained strong winds, pappi were violently released by thistle as heavy, entangled clusters, with seeds either not attached or trapped inside. Researchers concluded that only low numbers of seeds are propagated long distances by strong winds, and they estimate these have a slim chance of germinating and establishing new colonies.

On the other hand, Canada thistle stands generate a large number of seeds in close proximity, and these seedbanks are critical to the persistence of invasive stands.

What's Next?

Researchers recommended that Canada thistle management strategies focus less on wind dispersal and more on controlling the stand of thistle and the seedbank close to the parent plants. Education programs are needed to inform the public and land managers that the Canada thistle seedbank is really building close to home, and about the importance and proper timing of management decisions, such as determining when mowing and herbicide applications are most effective in controlling the thistle root system, thereby eliminating the controversy over seed flight altogether.

To refine our understanding of wind dispersal of Canada thistle and other winddispersed invasive plants, further study is needed about other factors influencing seed productivity and wind dispersal, including wind speed, turbulence and settling velocity, and the effects of the local environment on seed production and dispersal.



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TOTAL PROJECT COST: \$245,977



The new design is especially apt for short-span bridges common in rural areas where bridge closures result in long detours.

Validating Mn/DOT's Precast Composite Slab Span System

What Was the Need?

Precast elements have long been utilized in bridge construction because they speed construction times, and fabrication sites for these elements allow for a higher degree of quality control. However, older-style bridges incorporating precast hollow core panels have exhibited reflective cracking—cracking at the surface of the deck above the joints between the precast elements—which can necessitate significant maintenance or replacement costs.

Drawing on insights from an international scanning tour on accelerated bridge construction techniques as well as input from fabricators, contractors and academics, Mn/DOT engineers addressed the problem of reflective cracking with a Precast Composite Slab Span System, modeled after the Poutre Dalle system used in France. Mn/DOT's PCSSS removes the need for bridge deck formwork and is designed to simplify construction and reduce susceptibility to reflective cracking, using innovations such as "drop-in" reinforcement cages over the joint connections between the precast sections.

Mn/DOT's PCSSS can be applied to an important niche of bridges with relatively short spans (20 to 60 feet) that are currently served by cast-in-place slab-span bridges. Many of these bridges are nearing the end of their design life and are located in rural areas where bridge closures result in long detours and significant traffic disruption.

What Was Our Goal?

This project aimed to validate the performance of the new precast slab system through both field and laboratory work:

- In the field, the goals were to design and implement a detailed monitoring system for one of the new PCSSS bridges, followed by monitoring and analyzing the performance of the bridge for two years.
- The goal of the laboratory work was to perform a more controlled investigation of design characteristics and the effect of design variations (for example, in the amount of reinforcement, surface roughness or flange thickness) using a full-scale portion of a PCSSS bridge.

What Did We Do?

Researchers conducted a literature review of precast bridge systems, designed an overall instrumentation plan, selected the particular instruments needed, and installed the instrumentation in a three-span PCSSS bridge over the Center Lake Channel in Center City, Minnesota. They monitored the bridge for two years, analyzing the ongoing effects of the environment on the bridge structure.

A live-load test using trucks filled with sand was then performed, using seven singletruck and five paired-truck configurations. Among the characteristics investigated were the continuity of the bridge, whether live loads would likely lead to the development of cracks, and a comparison of the measured characteristics to those calculated during design.

Researchers identified modifications to the original Mn/DOT PCSSS design to improve system performance and economy, in particular reducing the thickness of the flange of the precast sections and increasing the spacing of some of the shear reinforcement. These modifications were applied to the construction of a two-span laboratory speci"Mn/DOT uses lots of slab-span bridges, but the biggest potential use of these bridges is on county and State Aid highways, not trunk highways. There are hundreds of bridges on the State Aid highway side that could be replaced with this design."

-Keith Molnau,

Design Unit #2 Leader, Mn/DOT Office of Bridges and Structures

"The main goal of the bridge design was to control cracking, but there were no detailed design guidelines for this bridge. We needed to understand whether the design models were valid."

-Catherine E. French, Professor, University of Minnesota Department of Civil Engineering

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Strain gages were embedded in the concrete decking above the longitudinal joints of the bridge, providing researchers with data to study the development of cracks above the joints.

men, which was instrumented both within the cast-in-place concrete (as in the field test) and within the precast sections themselves, and tested with a variety of loads.

The data from the Center City bridge and the laboratory tests were extensively analyzed, particularly with respect to cracking, transverse load distribution, pier continuity and structural stresses.

What Did We Learn?

The results of the field and laboratory study confirmed the durability of the Mn/DOT PCSSS, showing it to be a practical and economical accelerated construction alternative to cast-in-place slab construction.

Data from monitoring indicated that cracking had begun in some parts of the decking. The analysis showed that the cracks resulted from environmental factors and shrinkage rather than from vehicle loads. The types of cracking observed were not reflective, however; they did not extend through the section to the top surface and will not affect the bridge's safety or load-carrying capacity.

From the live-load truck test, the transverse load distributions determined from the strain gage measurements agreed well with the models considered.

The reduced thickness of the flange section performed well in the laboratory and improved both the resistance to cracking and the transverse load distribution; this is recommended as a general design modification to the Mn/DOT PCSSS.

What's Next?

The new bridge design is considered a success. Five more of these bridges have been constructed in Minnesota, and 11 are planned for installation in the next two to three years. The project received the 2008 University of Minnesota Center for Transportation Studies Research Partnership Award.

An additional project, <u>NCHRP 10-71</u>, is under way to further investigate these bridges, covering issues such as bursting, fatigue, composite action, extending the system to longer span lengths, and materials durability.

This Technical Summary pertains to two reports: Report 2006-37, "Application of Precast Decks and Other Elements to Bridge Structures," published September 2006, and Report 2008-41, "Monitoring and Analysis of Mn/DOT Precast Composite Slab Span System (PCSSS)," published September 2008. The full reports can be accessed at http://www.lrrb.org/PDF/200637.pdf and http://www.lrrb.org/PDF/200841.pdf, respectively.



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Principal Investigator: José Pincheira, University of Wisconsin—Madison

PROJECT COST: \$59,288



Extracted epoxy-coated bar samples underwent several tests; the dry knife adhesion test measures the adhesion of the coating to the bar.

Corrosion Performance of Epoxy-Coated Reinforcement Bars

What Was the Need?

Deteriorating reinforced concrete structures burden many of the nation's transportation departments with escalating repair and maintenance costs. The primary cause of this deterioration is the corrosion of the steel reinforcing bars inside the concrete. This corrosion is caused by exposure to chlorides from seawater in coastal areas and salt-based deicing chemicals in northern climates.

Bridge engineers have long used steel reinforcement bars coated with epoxy to minimize this corrosion, but policies and practices regarding the use of this coating have changed, and concerns remain about its effectiveness over the long term. A study conducted in 1996 by Wiss, Janney, Elstner Associates, Inc. of four 1970s-era Minnesota bridge decks determined levels of chloride concentrations and showed that some epoxycoated bars had initiated corrosion at cracks in the rebar coating, resulting in some cases in delamination of the concrete deck. Returning to those bridges with new technology to inspect their current condition would provide a data set extending nearly 35 years for analysis and evaluation of corrosion trends.

What Was Our Goal?

Researchers aimed to assess the corrosion performance over a 30- to 35-year period of epoxy-coated reinforcing bars in four bridge decks, providing bridge design engineers the data necessary to improve the long-term performance of Minnesota's reinforced concrete bridges.

What Did We Do?

Researchers performed field and laboratory measurements on four bridges (19015, 27812, 27815 and 27062) built between 1973 and 1978, and located in the Minneapolis/ St. Paul area.

In the field, researchers visually inspected the bridges looking for external signs of corrosion; dragged chains over the deck surfaces looking for areas where the concrete had delaminated; and recorded data from half-cell potential measurements, electrochemical spectroscopy and ground penetrating radar. In the laboratory, using core samples removed from the bridges, they measured the chloride content, carbonation depth, concrete density, diffusion rate, general characteristics of the epoxy coating on the bars, and the level of bar corrosion.

Data from the field and laboratory measurements was analyzed, cross-correlated and compared to previous studies to assess the overall performance of the reinforcing bars.

What Did We Learn?

Researchers found the bridge decks to be in generally good condition, showing light cracking, few delaminated areas and only modest corrosion. Only one deck (bridge 19015) had an open spalled (chipped) area. Overall, delaminated and spalled areas constituted less than 1.1 percent of the total area surveyed. The majority of the bars had a chloride ion content of 1.3 lb/cy or lower and had no signs of corrosion. Most of the bars with a chloride ion content of 5.3 lb/cy or higher showed some corrosion.

One bridge (19015) exhibited corrosion, primarily around the joints over the bridge piers. However, the bars did not indicate any section loss. In general, chloride ion corrosion levels and corrosion were greater near joints and vertical cracks. Researchers

"Overall, the bars extracted looked good. We found some that had begun to corrode, but localized to the joints and vertical cracks in the bridge."

–José Pincheira,

Associate Professor, University of Wisconsin— Madison Department of Civil and Environmental Engineering

"We were glad to see that the coating was performing effectively and that our specifications won't require any significant changes."

-Paul Rowekamp, Mn/DOT Bridge Standards & Research Engineer

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Researchers used ground penetrating radar (pictured), impedance spectroscopy and half-cell potential measurements in the field to evaluate the level of corrosion of the bars.

recommended that these locations be sealed to prevent deicing agents and humidity from having direct access to the reinforcing bars.

Based upon the gathered data and modeling of the rate of increase in chloride concentration near the bars, those bars located away from cracks or joints and covered by at least 3.5 inches of overlay should not corrode for another 20 to 25 years.

Two of the bridges (27812 and 27815) had decks with 2.5 inches of low slump: highdensity overlays that decreased the amount of diffusion through the deck and likely lowered the chloride content at the bars, suggesting that such overlays can improve the performance and extend the service life of bridge decks.

Mn/DOT bridges have two levels of reinforcing bars (termed "mats") within the concrete structure. Past practice had been to coat only the upper mat because it was closest to the surface, while current practice is for both mats to utilize epoxy-coated bars. Researchers found no sign of increased corrosion activity in coated bars in the bridge with a lower mat of uncoated bars, nor any signs of electrochemical interaction between the coated and uncoated bars that would increase corrosion. Though no lower-mat uncoated bars were examined in the study, rust stains on the bottom of the deck suggested corrosion activity in these bars.

Overall, current Mn/DOT practices were found to be effective, and researchers recommended they be continued. Based upon current fabrication techniques, researchers expect that the epoxy-coated bars made today would be at least as corrosion-resistant as those examined in the study.

What's Next?

This study was part of a long-term monitoring program. The study may be repeated in another decade to re-examine the health of the reinforcement of these bridges.

Mn/DOT Research Services is considering conducting after-the-fact surveys to gauge the degree to which the workshop facilitated changes in practice at the local level.

This Technical Summary pertains to Report 2008-47, "Corrosion Protection Performance of Epoxycoated Reinforcing Bars," published September 2008. The full report can be accessed at <u>http://www.lrrb.org/PDF/200847.pdf</u>.



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Principal Investigator: Peter Graham, University of Minnesota

PROJECT COST: \$103,375



Purple prairie clover is a legume used in prairie restoration.

Improved Methodologies for the Inoculation of Prairie Legumes in Roadside/Revegetation Settings

What Was the Need?

Agricultural development over much of the 400 million acres of prairie grassland in the Great Plains has resulted in significant declines in tallgrass (99.9 percent decline), mixed grass (61 percent) and shortgrass (85.5 percent). Prairie restoration offers substantial environmental benefits, and planting low-maintenance prairie grassland is an important part of Mn/DOT's strategy to control roadside erosion. If the native prairie areas can become self-sustaining, Minnesota's roadsides can be both attractive and less expensive to maintain. However, prairie restoration can be a slow, multiyear process.

Researchers have identified that legumes are integral to prairie development; where legumes have not been successfully planted, prairie development is delayed. Legumes pull nitrogen gas—unusable by most living organisms—from the air and convert it to a biologically useful ammonia form of nitrogen. The roadside soils where the prairies are being re-established are often compacted and lack the bacteria needed by legumes to pull nitrogen out of the air. Inoculating legumes with appropriate bacteria can help compensate for deficient roadside soils and encourage more rapid prairie development.

Mn/DOT includes a number of indigenous legumes in its roadside vegetation and wetland restoration plant mixes. A <u>Mn/DOT-funded study completed in 2004</u> identified new inoculant cultures for the legumes being used by Mn/DOT. Improved methods of legume inoculation and better inoculant delivery systems are needed to ensure that the strains being used are effective under revegetation conditions.

What Was Our Goal?

The objectives of this study were to:

- Identify and test methods for the use of cereal crops like winter wheat and rye as a carrier for inoculating bacteria for prairie legumes.
- Evaluate different methods for effectively inoculating prairie legumes in a restoration setting.
- Determine the feasibility for the inoculation of legumes growing in heavily fertilized seed blankets.

What Did We Do?

Researchers first conducted a series of field and greenhouse trials to evaluate 33 cereal crops as inoculating carriers for the soil bacteria associated with prairie legumes. In the second part of the study, researchers established prairie areas at the University of Minnesota Sand Plain Research Farm over a three-year period to test several treatments at four areas each: granular clay-based inoculant, granular peat-based inoculant, seed-applied powdered peat inoculant, inoculated wheat seed applied as a cover crop, and uninoculated. Finally, they conducted a greenhouse experiment using pregerminated seed blankets with prairie mix seeds to test nitrogen rates and their effect on legume establishment following inoculation.

What Did We Learn?

With two exceptions, all fall-planted cereals and grasses tested regrew during the following season. Researchers noted that "Roughrider" wheat cultivar exhibited the best "The results of this study show strong benefits with the methods identified in the research. We can apply these methods in field trials as a first step in modifying our seeding specifications."

-Kenneth Graeve, Botanist/Plant Ecologist, Mn/DOT Office of Environmental Services

"The ability to fix nitrogen in symbiosis is important for more than prairie restoration. If biofuel crops are to be efficient and sustainable, they also will need to be associated with nitrogen-fixing legumes and to satisfy their nitrogen needs through symbiosis."

-Peter Graham,

Professor, University of Minnesota Department of Soil, Water and Climate

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Prairie plantings like this one in Minnesota are thought to help in the fight against global warming. Prairie restoration is critical for agricultural and wildlife maintenance.

results, and they recommended that it be studied further. They found that inoculating seed blankets was impractical because of the high levels of nitrogen fertilization used on seed blankets to achieve sufficient growth before the blankets are applied in the field.

Seed inoculation was found to be generally ineffective as well, but overall legume numbers in the prairie restorations were enhanced by both soil-applied granular and cover-crop applied inoculants, with the better inoculation practices also resulting in soil quality improvement over the course of the study. Inoculant rhizobia for *Dalea* accounted for 90 percent to 100 percent of the strains recovered from soil in the soil-applied granular peat and cover-crop-inoculated treatments, but only 4 percent in the seed-inoculated treatments, showing clear differences in the establishment of these organisms. Researchers preferred the granular peat-based inoculation treatment, citing uniformity of response and convenience of use. Increasing the number of bacteria applied was found to clearly benefit prairie establishment and function.

What's Next?

Recommendations from this study include:

- Using granular soil-applied peat inoculant for prairie seeding and restoration activities. Study results indicate the need to inoculate *Dalea purpurea* and *D. candida*; results with *Desmodium* were less clear.
- Fall seeding followed by spring inoculation so that the soil bacteria need not survive through the winter before legumes begin to germinate.
- A review by Mn/DOT to locate sources for peat, including an evaluation to ensure suitability for use in inoculant production. Implementing this study's recommendations will result in a substantial increase in the amount of peat needed for Mn/DOT's restoration activities.

Mn/DOT will evaluate these recommendations in upcoming field testing before making formal changes to its seeding specifications. This is only the second study that examines inoculation in connection with prairie establishment. Further research over a longer study period is needed to identify the best possible inoculants that will fix nitrogen, stay alive in the soil, compete effectively with stray bacteria and tolerate difficult environmental conditions over time.

This Technical Summary pertains to Report 2008-48, "Improved Methodologies for the Inoculation of Prairie Legumes in Roadside/Revegetation Settings," published October 2008. The full report can be accessed at http://www.lrrb.org/PDF/200848.pdf.



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PROJECT COST:

\$99,132



Reed canarygrass has been increasingly invading Minnesota's wetlands.

Investigating the Effects on Wildlife of Reed Canarygrass Infestation of Minnesota Wetlands

What Was the Need?

Wetlands are known for their susceptibility to invasive plants. During the past few decades, diversity and complexity of native plant communities in southern Minnesota wetlands have become threatened by reed canarygrass, a perennial, cool-season grass that outcompetes native vegetation. This invasion is often associated with disturbances such as ditch building and stream channeling sedimentation, and with intentional planting for forage and erosion control.

Mn/DOT is often required to manage reed canarygrass when preserving and restoring wetlands. Wetland mitigation agreements with regulators such as Minnesota's Board of Water and Soil Resources and the U.S. Army Corps of Engineers are becoming stricter, and there is increasing pressure on Mn/DOT to manage this invasive plant. Mn/DOT needs to understand any cascading effects of the invasion of reed canarygrass as it manages its wetland mitigation efforts in Minnesota.

The diversity of animals in any habitat is related to the structure, complexity and diversity of vegetation. Habitats that contain reed canarygrass have been found to have a less diverse mix of traditional native plants, so it is reasonable to expect that reed canarygrass will have a corresponding negative effect on wildlife. While some studies have demonstrated this impact, Mn/DOT knows little about the specific effects on Minnesota wildlife.

What Was Our Goal?

The objective of this study was to determine the effects of reed canarygrass by comparing the ability of sites invaded by reed canarygrass to support wildlife with sites dominated by native vegetation. Specifically, researchers wanted to compare these sites with respect to the composition, diversity and production of plant species, and the composition and diversity of wildlife species.

What Did We Do?

Researchers established sampling plots at eight paired sites in five counties of the farmland region of southern Minnesota. They selected four wetlands dominated by reed canarygrass and four sites with native wetland vegetation that were close in proximity and similar in size and landscape position. Locating healthy, nonimpacted wetlands was difficult; reed canarygrass was present, to some degree, in at least two of the native sites. Data was collected at sampling plots beginning in the spring of 2006 through the fall of 2007.

Researchers evaluated the effects of reed canarygrass invasion on plants, birds, mammals and invertebrates (chiefly, insects). They hypothesized that all four communities would be negatively affected by the invasion of reed canarygrass and expected to find effects more evident for organisms lower on the food chain (green plants) than for those higher up (that is, herbivores, then carnivores).

What Did We Learn?

Results of the study did not consistently support the researchers' hypothesis that the invasion by reed canarygrass will have a negative effect on wildlife. Study results indicated that:

"The fact that we were unable to find four native study sites completely free of reed canarygrass highlights the significance of this problem."

-Kenneth Graeve, Botanist/Plant Ecologist, Mn/DOT Office of Environmental Services

"An interesting and unexpected result of this study was that invaded areas were not a monoculture of reed canarygrass; most of the plant species were still there, but not in abundance."

-Brock McMillan,

Professor, Minnesota State University— Mankato Department of Biological Sciences

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Two of the sites used to study the effects of reed canarygrass invasion on wildlife: The Rasmussen Lake study area (left) has been invaded by reed canarygrass, while the Ottowa study area (right) is dominated by native vegetation.

- In 2007, a significant loss in plant species richness and diversity was noted in sites invaded by reed canarygrass as compared with other sites. (For 2006, the sampling method was not designed to make this comparison, measuring instead the total diversity.)
- There was no evidence that the bird community was negatively influenced by the invasion of reed canarygrass. The only significant finding indicated that the number of species of birds was actually greater at sites invaded by reed canarygrass in one of the two study years, suggesting that bird diversity is influenced more by structure than plant diversity; since invaded sites have more structure, they would have richer bird diversity.
- Diversity of small mammals was lower at sites invaded by reed canarygrass during 2006, but not during 2007. Researchers indicated that a single difference during a single year suggests that the relationship between invasive reed canarygrass and small mammals may not be strong in the sampling plots.
- As researchers expected, the effects of reed canarygrass invasion were more evident for organisms lower on the food chain. Study results indicated lower richness and diversity of insects at sites invaded by reed canarygrass.

What's Next?

The results of this study do not demonstrate a clear negative impact on wildlife from the invasion of reed canarygrass. Researchers did note that the effects of reed canarygrass were more evident for organisms lower on the food chain, negatively influencing the plant and invertebrate communities. This study suggests that more comprehensive research of the vertebrate community is needed—examining more sites over a longer study period—to determine whether there are clear and consistent effects of reed canarygrass invasion on wildlife levels.





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PROJECT COST: \$264,000



Researchers instrumented all girders inside and outside.

Self-Compacting Concrete for Prestressed Bridge Girders

What Was the Need?

Traditional concretes used in precast bridge elements require vibration during construction in order for the wet concrete to fully fill the casting forms. Even with vibration, cast concrete structures require significant labor after the initial casting to fill "bug" holes and improve the surface finish. Self-compacting concrete was first developed in Japan in the early 1980s to eliminate some of these construction inefficiencies. SCC is highly workable and flows through congested reinforcement areas under its own weight alone, filling formwork with a structure free of voids and without the need for applied vibration. Constructing bridge girders with SCC could significantly reduce the labor cost in precast applications.

However, there is limited literature available evaluating the long-term behavior of SCC girders, and the findings among even those studies vary greatly. Also, the American Society for Testing and Materials has not issued test methods that can be used to evaluate the concrete in its fresh state and accurately predict its behavior when hardened. Both Mn/DOT and local concrete girder manufacturers have little experience in handling SCC and understanding its long-term behavior. Such experience is necessary to produce beams with consistent physical properties. Lastly, current highway bridge codes do not distinguish between conventional concrete and SCC, though these have significant differences. Mn/DOT engineers and fabricators need to consider these differences and how to handle them during inspections.

Prior to using SCC in bridge construction to take advantage of the cost-saving benefits of the material, Mn/DOT needed to understand both the wet and hardened characteristics of the concrete in real-world applications; data gathering was needed to evaluate the possibility of future use in building bridge girders in Minnesota.

What Was Our Goal?

The goals of this study were:

- To determine a reasonable SCC mix design using locally available materials and methods that could be implemented at Minnesota precast concrete plants
- To examine girders fabricated with SCC in the laboratory and compare their characteristics to girders made using conventional concrete

What Did We Do?

Researchers evaluated the performance in a wet state of 17 mixes using different cements, aggregates and admixtures with varying proportions. Quantitative measurements such as slump flow (characterizing the amount that the wet concrete flows) and qualitative measurements such as visual inspection were all used to summarize the performance of the mixes. Evaluating these mixes in consultation with local plant personnel, researchers determined appropriate SCC mixes. Four SCC and two conventional, 38-foot, full-scale Mn/DOT 36M I-girders were cast from the same forms at two precast concrete plants.

The girders were instrumented to monitor both long-term and short-term performance under laboratory tests. Researchers used design tools and specifications from AASHTO (2007) and ACI 318 (2005) to predict the results and evaluate the tools for their applicability in designing SCC bridge girders. Additionally, a large number of cylinders were fabricated using the SCC mix and used to monitor characteristics such as compressive

"Mn/DOT is more confident now that beams produced with SCC have been shown capable of providing satisfactory, long-term performance in Minnesota bridges."

-Erik Wolhowe,

Bridge Consultant Contracts Coordinator, Mn/DOT Metro District

"Because SCC does not need vibration to be consolidated, faster construction is possible with less labor and potentially large economic benefits."

-Carol Shield,

Professor, University of Minnesota Department of Civil Engineering

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To find an SCC mix that had the necessary viscosity and flow properties in the fresh state, researchers performed a series of mixing tests.

strength and stiffness, and develop models for creep and material shrinkage.

What Did We Learn?

SCC with adequate performance in the fresh state was successfully developed for fabrication of Mn/DOT bridge girders, using locally available materials at two precast concrete plants in the Twin Cities area.

Some chemical and physical properties of cement that are not typically listed in the mill report for the cement were found to significantly affect the flow properties of SCC. Among the matters explored, researchers found that the flowability of SCC increases about 1 inch for each 10 degrees Fahrenheit increase in mixing temperature, and SCC girders have longer transfer lengths than conventionally made girders.

What's Next?

Overall, Mn/DOT engineers were pleased with the results and are confident SCC can be used in the future to construct precast bridge girders.

Further understanding of the sensitivity of the fresh-state properties of SCC to the original cement is the most pressing hurdle to large-scale implementation of SCC as the preferred concrete in constructing these girders. Fabricators also need more experience with the mixing process to make concrete that has the same properties batch after batch. Since the conclusion of this research project, several fabricators have been experimenting with high-slump concrete and producing beams successfully.

State Planning & Research Reports

State Planning & Research funds are received from the federal government for Mn/DOT planning and research activities; 25 percent of these funds are to be used specifically for research, to address state-specific research needs. These funds can be used for participation in multistate pooled fund efforts or in single-state efforts, often in technology transfer, though also in research into new areas of knowledge or application of research findings through development of new technologies.

Mn/DOT has been a leader in multistate efforts, as detailed in the Active Multi-State Pooled Fund list in the *At-A-Glance* document. Research Services has published the following SP&R-supported reports in 2008. We have produced a Technical Summary for 2008-22; because this work was co-funded with the State Research Program, it can be found in the section immediately preceding this one. The Technical Summary for 2008-27, which was co-funded by SP&R and the Mn/DOT Office of Traffic Safety and Technology; can be found with the summaries in "Other Research Reports."

2008-18	MnROAD Cell 54—Cell Constructed With Mesabi-Select (Taconite-Overburden) Aggregate: Construction and Early								
	Performance Report								
2008-22	Intelligent Compaction Implementation: Research Assessment								
2008-27	The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable								
	Message Signs—Phase II								
2008-30	Review of New Hampshire's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection								
	Decision Support (IDS)								
2008-31	Review of Nevada's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection Decision								
	Support (IDS)								
2008-45	Report of Pavement Surface Characteristics Mini-Rodeo (Mn/DOT Test Data and Data								
	Comparison)								
2008-46	Evaluation of Concrete Pavement Texturing Practices in Minnesota Using the Wet Weather Accident Evaluation Criterion								
2008-48	Improved Methodologies for the Inoculation of Prairie Legumes in Roadside/Revegetation Settings								
2008-49	The Wildlife Value of Reed Canarygrass Infested Wetlands in Minnesota								
2008-51	Self Compacting Concrete (SCC) for Prestressed Bridge Girders								
2008-52	Review of California's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection								
	Decision Support (IDS)								
2008-53	Overview of Rural Intersection Crashes at Candidate Intersections for								
	the Intersection Decision Support (IDS) System								
PEEREX07	MPR-6(002) Financial Peer Exchange								
BIKEPED08	IMP2006 #2: Promoting the Bicycle and Pedestrian Toolbox								
TRS0801	INV: 881: Transportation Research Synthesis—Traffic Calming for								
	High-Speed Rural Roadways								
TRS0802	Methods of Estimating the Economic Impact of Transportation Im-								
	provements								
Other Research Reports

Research Services has published reports produced with research funds from other Mn/DOT departments, and we are sometimes able to publish reports acquired in some other way.

For 2008, reports in these categories are shown in the following table, indicating the funding Mn/DOT department, when applicable. Each bolded report below is discussed in a two-page Technical Summary presented in this section. Note that as 2007-17 was jointly funded by the State Research Program and Intelligent Transportation Systems, and 2008-21 was jointly funded by the Office of State Aid and the State Research Program and the Office of Maintenance, the Technical Summaries for these projects can be found with the preceding State Research Program summaries.

2008-17	Cross Median Crashes: Identification and Countermeasures	State Research Program/ Intelligent Transportation Systems
2008-21	Development of a Trash Harvester for Mn/DOT—Phase II	State Research Program/ Office of Maintenance
2008-38	Access to Destinations: Computation of Travel Time Data for Access to Destinations Study	N/A
2008-34	Perceptions of the View from the Road AIMS II: A Statewide Web Survey—Aesthetic Initiative Measurement System Phase II	N/A
2008-43	Improving Carsharing and Transit Service with ITS	Intelligent Transportation Systems/ Office of Traffic Safety & Technology
2008-44	Safety Effects of Centerline Rumble Strips in Minnesota	N/A
2008-27	The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable Message Signs—Phase II	State Planning & Research/ Office of Traffic Safety & Technology



The Office of Maintenance co-funded a project (Report 2008-21) with the Mn/DOT State Research Program to develop and test an automated off-road litter removal system for the Twin Cities; though the results were mixed, the project provided a solid base from which to perform additional research and design.



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Principal Investigators:

Kathleen A. Harder, University of Minnesota John R. Bloomfield, University of Minnesota

PROJECT COST: \$88,000



The STISIM simulator uses three PCs to generate a virtual environment presented on 17-inch monitors.

The Effectiveness and Safety of Non-Traffic-Related Messages on Changeable Message Signs

What Was the Need?

Changeable message signs are electronic devices used along roadways to provide drivers with guidance related to traffic conditions and other events. Displayed messages can suggest that drivers take alternate routes in response to congestion, accidents or roadwork zones. CMSs are also used to display time-critical information not related to traffic control, such as Amber alerts regarding child abductions, as well as messages not specific to a time or roadway condition, such as "Don't Drink and Drive."

Evidence suggests that CMSs can disrupt traffic flow by causing drivers to slow down. Further, the content of messages displayed on CMSs may not be adequately comprehensible to allow drivers to respond to them appropriately. Finally, using CMSs to display both messages that are time-critical and those that are not may lead drivers to pay less attention to either type of message.

Phase I of a study into these issues, conducted in 2003, measured the effect of the more complex CMS messages Mn/DOT was using at the time. Further study was needed to perform assessments of CMSs with newly developed wording that more clearly conveyed the intended message to drivers.

What Was Our Goal?

The purpose of Phase II was to evaluate how lowering the complexity and ambiguity of CMS messages would affect driver behavior and traffic flow. By performing the same assessments on Phase II messages that were performed in Phase I, investigators aimed to compare how well the suggested guidance was followed and the degree to which CMSs led drivers to slow down.

In Phase II, investigators also wanted to determine:

- The validity of simulator speed-reduction data in comparison to real-world data
- Driver attitudes toward the utility of CMSs
- The efficacy and efficiency of Mn/DOT's Regional Transportation Management Center management of CMS deployments

What Did We Do?

This study assessed the behavior and opinions of 120 licensed drivers from three age groups (18 to 24, 32 to 47 and 55 to 65 years) consisting of 40 participants each. Researchers used a computer-based driving simulator to conduct two experiments on driver responses to CMSs that were directly comparable to experiments in Phase I. They supplemented these findings using a survey to assess whether drivers think it is useful to have traffic-related information presented on CMSs. They then conducted observations at RTMC focusing on the decision-making processes involved when traffic-related CMS messages are deployed.

In the simulation experiments, each participant sat in a driving simulator consisting of an automotive-style seat for the driver facing a bank of three 17-inch CRT monitors, which displayed a virtual environment consisting of a four-lane freeway. Participants drove for approximately 20 miles on the simulated roadway in low-level traffic. In the first experiment, participants encountered a time-critical, site-specific CMS message "This study provided valuable information to validate our operating procedures, the way we structured the new messages and the fact that the content of the CMS messages is more important than their location."

-Todd Kramascz,

Operations Supervisor, Traffic Operations Section, Mn/DOT Regional Transportation Management Center

"The empirical data shows that when you design message content that drivers will more easily understand, they are more likely to respond appropriately."

-Kathleen A. Harder,

Senior Research Associate, University of Minnesota Center for Human Factors Systems Research and Design

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This is a typical view of the simulated environment that participants saw on their center display. In this case, a site-specific, time-critical message advises participants to take an exit.

advising them to leave the freeway at a specific exit. In the second experiment, participants encountered a time-critical, non-site-specific CMS displaying an "abducted child" message. Phase II messages were more clearly worded and less complex than those used in Phase I.

What Did We Learn?

Researchers learned that:

- Clarifying the content of CMS messages led to a correct response from significantly more participants (for site-specific messages, 93.3 percent in Phase II compared with 55.8 percent in Phase I; for non-site-specific alerts, 71.7 percent for the abducted child message in Phase II compared with 8.3 percent for the Amber alert message in Phase I).
- Drivers may reduce speed as they approach CMS messages in free-flow conditions, but are probably less likely to need to reduce speed in the typically lower speeds of congested traffic.
- Real-world data were limited, but consistent with the suggestion that deploying CMS messages can lead to slower driving speeds in real-world driving.
- Drivers thought that using CMS displays to present information about traffic problems and roadway maintenance schedules was very useful, and that display of travel time information was useful. Their responses to safety messages on CMS displays were mixed.
- Current RTMC decision-making processes are sound and efficient: Operators responded to incidents quickly and managed them effectively.

What's Next?

As new technologies are developed, CMSs will continue to be enhanced, and newer devices will require testing. Apart from studying the effects of CMSs using new technologies, there is a need for a more granular study of various messaging possibilities to identify the safest and most effective ways to inform drivers of roadway conditions and other information. Such studies could yield a knowledge base of driver responses to various CMS messages, leading to an increased level of safety on state and national roads.

This Technical Summary pertains to Report 2008-27, "The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable Message Signs—Phase II," published August 2008. The full report can be accessed at http://www.lrrb.org/PDF/200827.pdf.



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Principal Investigator: Frank Douma, University of Minnesota

PROJECT COST: \$102,313



Metro Transit's online trip planner has received positive response.

Improving Carsharing and Transit Service with ITS

What Was the Need?

Intelligent Transportation Systems refers to any use of information and communications technology to solve surface transportation problems. Recent research into how ITS can best serve Minnesota's diverse population indicates that two ITS applications—carsharing and Advanced Transportation Information Services—could bring significant benefits by providing travelers with increased mobility and access to transit services.

Carsharing is the practice of renting cars for short periods, usually by the hour; this option encourages participants to give up car ownership and related fixed costs. In 2005, Mn/DOT supported <u>a market assessment to determine the potential for carsharing in the Twin Cities</u>. Shortly afterward, the HOURCAR carsharing organization began offering service in the Twin Cities. While not directly involved in CSO operations, Mn/DOT has a stake in helping value-pricing strategies like CSOs succeed, and helping them to better understand their customers will increase the likelihood that these programs will remain viable.

Advanced Transportation Information Services applications, like the online public transit sites used to locate transit route information and plan trips, are becoming more prevalent and often serve as the only communication point between the user and the transit service. Understanding how users' interactions with these ATIS applications affect their perceptions of the agency and its services will allow agencies to improve their services.

What Was Our Goal?

The objectives of this research were to:

- Gather information about the carsharing market in the Twin Cities to make recommendations for improvements to CSO providers.
- Gather information regarding how citizen perceptions of trust and confidence in a public transit agency and its service are affected by the use of an online trip planner.

What Did We Do?

Researchers approached the two elements of the study with different research strategies.

Carsharing. At the time of the study, two CSOs operated in the Twin Cities: HOURCAR and Zipcar. Zipcar elected not to participate in the study.

In the fall of 2007, HOURCAR, a nonprofit CSO, operated 15 neighborhood hubs with one or two cars at each hub. During a three-week period from September to October 2007, researchers administered an electronic survey of 28 questions to members of HOURCAR and a control group, randomly selected from residents of census tracts containing HOURCAR hubs. Researchers analyzed 152 responses from the control group and 186 HOURCAR member responses. An electronic copy of a travel log was provided for participants to fill in the trips they made on a single weekday.

ATIS. Researchers used surveys and focus groups to investigate an online trip planner developed and maintained by Metro Transit, the largest transit provider in the Twin Cities. Links to an online survey designed to inquire about user experiences with the online trip planner were placed on the Metro Transit Web site during the month of March 2008, resulting in 446 completed surveys. To gain more in-depth understanding of user perceptions, researchers conducted two 90-minute focus group sessions, which were attended by 24 survey respondents.

"Carsharing organizations in the Twin Cities can use the results of this study to more thoroughly understand their market and adjust their services to make their programs more viable."

-Ken Buckeye,

Program Manager, Mn/DOT Office of Policy Analysis, Research & Innovation

"This study demonstrated that ITS can be used to promote alternative travel modes as well as more conventional, highwaybased applications."

-Frank Douma,

Assistant Program Director, State and Local Policy Program, University of Minnesota Hubert H. Humphrey Institute of Public Affairs

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Minnesota Department of Transportation Research Services Section MS 330, First Floor 395 John Ireland Blvd. St. Paul, MN 55155-1899 (651) 366-3780 www.research.dot.state.mn.us



Fewer members owned cars (blue) after joining HOURCAR (group 4) than before joining (group 3), but this group's ownership rates were much lower before joining than the population as a whole (group 1).

What Did We Learn?

Results of the carsharing survey included:

- Auto ownership declined among CSO members in nearly all cases. Researchers' extrapolated calculations indicated that each HOURCAR removes 2.5 other vehicles. However, HOURCAR members surveyed showed a low level of private vehicle use as compared to the population even before joining HOURCAR.
- HOURCAR members displayed no significant demographic differences from the control group.
- Convenience and financial considerations were the primary motivations for joining HOURCAR, not environmental considerations.

For the ATIS element of the study, researchers found:

- A strong positive view of the trip planner, including generally positive responses to its new features. This service was found to help increase trust in Metro Transit.
- Negative experiences, including bus driver behavior and attitudes, customer service functions, as well as bus and bus stop cleanliness, affected how participants perceived Metro Transit.

The online transit trip planner could provide a means for improving perceptions of trust and confidence by mitigating these negative experiences.

What's Next?

The results of this study are being presented at the 2009 Transportation Research Board Annual Meeting. Mn/DOT is supportive of continuing research into the viability of CSOs. Further research could be pursued under the Federal Highway Administration's Value Pricing Pilot Program. This competitive solicitation provides funding to support studies of a value-pricing project, like a CSO, that manages congestion on highways through tolling and other pricing strategies. Additional research might include a follow-up survey in a couple of years to assess the ongoing travel choices of HOURCAR members, including the impact of higher costs of car ownership on CSO member travel behavior.

This Technical Summary pertains to Report 2008-43, "Improving Carsharing and Transit Service with ITS," published September 2008. The full report can be accessed at http://www.lrrb.org/PDF/200843.pdf.



TECHNICAL SUMMARY

Administrative Liaison: Sandra McCully, Mn/DOT sandy.mccully@dot.state.mn.us

Principal Investigator: Marc Briese, City of Woodbury

> PROJECT COST: \$0



Grinding machines in Minnesota use specially designed cutting teeth to mill rumble strips, creating both sides in a single pass.

Safety Effects of Centerline Rumble Strips in Minnesota

What Was the Need?

Government transportation agencies must continually look for ways to improve safety and reduce the number of accidents on roadways. Minnesota's numerous rural two-lane roadways require particular attention, as these roads generally have only a 12-inch-wide centerline separating opposing traffic, making them vulnerable to vehicles crossing into the opposing lane and crashing into an oncoming vehicle head-on or sideswiping it.

These crashes are the most severe types of crashes both in terms of injuries and costs, and they account for 25 percent of all crashes on Minnesota rural two-lane roads, while accounting for only 11 percent of crashes statewide.

Rumble strips in the centerline (grooves in pavement that, when driven on, produce an audible "rumble" and vehicle vibration) provide a potential low-cost way of reducing these crashes. Shoulder rumble strips have been used for years to reduce the number of run-off-the-road crashes. Centerline rumble strips are gaining momentum nationally and internationally as an effective countermeasure for centerline crashes. These strips alert drivers that they have begun to cross over into oncoming lanes of traffic.

What Was Our Goal?

The objectives of this research were to examine the relationship between centerline rumble strips and traffic safety on rural roads, and to recommend best practices for using these strips.

Given the extremely severe nature of centerline-crossing crashes and their overrepresentation on rural two-lane roads, targeting these crashes for reduction by using centerline rumble strips presents an excellent opportunity to help save lives in Minnesota.

What Did We Do?

Researchers examined crash statistics from 203 miles of Minnesota rural roadways from Mn/ DOT's Office of Traffic, Safety and Technology, including such resources as video surveillance data from District 3, where most centerline rumble strips in Minnesota are concentrated. To determine the effect of these strips on accident reduction, investigators considered variables such as vehicle speed, lateral placement of vehicles on tangent sections and centerline encroachment. This information was used for two types of analysis:

- **Before-After Crash Analysis:** This method simply counted the total number of crashes in the predefined period "before centerline rumble strips" and compared it to the total number of crashes in the period "after centerline rumble strips."
- **Cross Section Analysis:** A cross-sectional study compared safety performance of similar roadways during the same years, with a treatment group that contained roadways with centerline rumble strips measured against a control group that did not.

What Did We Learn?

In the before-after analysis, the presence of strips had a profound effect on centerline encroachments and crossings; reductions in encroachments ranged from 40 percent to 76 percent. There were fewer encroachments on horizontal curves; neither did vehicles drive closer to the shoulder. The number of centerline-crossing crashes was reduced, though the number of crashes central to this study (where opposite-traveling vehicles crash head on or sideswipe, or a car goes off the left side of the road) showed no improvement. The overall crash rate increased slightly (as more vehicles were reduced. Though the overall crash rate increased slightly (as more vehicles were added "In these tight budget times, justifying extra cost is tough. But the relationship between centerline rumble strips and accident reduction is clear. And the benefits are simple: saving lives."

-Marc Briese, Traffic Engineer, City of Woodbury

"Because Marc Briese conducted this study as the Capstone project for his infrastructure systems engineering degree, there was no cost to Mn/DOT in acquiring this valuable research."

-Sue Lodahl,

Director, Mn/DOT Research Services Section

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After grinding is complete, a street sweeper removes debris from the road. A finished stretch of road, complete with centerline rumble strip, is shown here.

to the roads over the time period), but the severity of crashes decreased slightly.

In the cross section analysis, the treatment group (with strips) experienced a 73 percent lower rate of fatal and very severe crashes, a 42 percent lower crash rate overall, a 37 percent lower crash severity rate and a 19 percent reduction in crash density (the number of crashes per mile).

Overall, the results show that roads with centerline rumble strips exhibit better safety characteristics than roads without these strips. At \$1,000 per mile, centerline rumble strips offer a costeffective way to increase safety on rural two-lane state and county roads.

What's Next?

To systematically implement centerline rumble strips, Mn/DOT needs to promote the strips' safety benefits (to secure funding) and define best practices in their use. Mn/DOT's Safety unit is currently working on research to update and verify this project's findings with a more extensive literature review and analysis of a larger pool of crash data from multiple states.

Preliminary recommendations on the use of centerline rumble strips given in the report include:

- Developing a policy for installing the strips with a phased, statewide implementation strategy based on data such as existing crash characteristics, average daily traffic or future construction plans
- Standardizing guidance on strip design and placement, where locations receiving the strips have them installed continuously and not just in no-passing zones
- Defining possible treatments to the strips to increase the longevity of the centerline pavement, including fog sealing or spraying with a black epoxy

This Technical Summary pertains to Report 2008-44, "Safety Effects of Centerline Rumble Strips in Minnesota," published December 2006. The full report can be accessed at http://www.lrrb.org/PDF/200844.pdf.

2008 Active NCHRP Projects with Mn/DOT Panel Membership

Project Number	Project Title	Mn/DOT Panel Member	Start Date	End Date
D0141	Models for Predicting Reflective Cracking of Hot-Mix Asphalt Concrete Overlays	Bruce Chadbourn	2005	2008
D0142	Models for Predicting Top-Down Cracking of Hot-Mix Asphalt Layers	Shongtao Dai	2006	2008
D0146	Development of an AASHTO Pavement Handbook	Curt Turgeon	Anticipated	Anticipated
D0362	Guidelines for Accessible Pedestrian Signals	Beverly Farraher	2001	2010
D0391	Left-Turn Accommodations at Unsignalized Intersections	Brian Gage	2008	2009
D0836B	Research for the AASHTO Standing Committee on Planning	Timothy Henkel	Pending	Pending
D0857	Improved Framework and Tools for Highway Pricing Decisions	Kenneth Buckeye	2006	2008
D0860	Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Cost	Tim Henkel	2007	2009
D0862	Transportation Performance Management Programs-Insight from Practitioners	Mark Larson	2007	2009
D0863	Review of Canadian Experience with Large Commercial Motor Vehicles	Cecil Selness	2007	2008
D0867	Integrating Individual Transportation System-Level Performance Programs to Determine Network Performance	Mark Nelson	2008	2009
D0868	Citizen's Guide and Discipline-Specific Professionals' Guide for Context-Sensitive Solutions in Transportation	Scott Bradley	2008	2010
D0870	Target-Setting Methods and Data Management To Support Performance-Based Resource Allocation by Transportation Agencies	Rabinder Bains	2008	2010
D0871	Methodology for Estimating Life Expectancies of Highway Assets	Mark Nelson	Pending	Pending
D0875	Peformance Measurement and Evaluation of Tolling and Congestion Pricing Project Benefits and System Impacts	Kenneth Buckeye	Pending	Pending
D0930A	Calibration of Rutting Models for HMA Structural and Mix Design	Shongtao Dai	2005	2009
D0940	Optimization of Tack Coat for HMA Placement	Roger Olson	2005	2009
D0943	Mix Design Practices for Warm Mix Asphalt	Timothy R. Clyne	2007	2010
D1071	Evaluation of CIP Reinforced Joints for Full-Depth Precast Concrete Bridge Decks	Daniel Dorgan	2006	2009
D1280	LRFD Minimum Flexural Reinforcement Requirements	Keith Molnau	2008	2009
D1532	Context Sensitive Solutions: Quantification of the Benefits in Transportation	Scott Bradley	2006	2009
D1533	Guide for Transportation Landscape and Environmental Design	Scott Bradley	2006	2009
D202454G	2006 AASHTO Bottom Line Scoping	Jonette Kreideweis	2007	2009
D202455	National Summit on Future Transporation Funding and Finance Strategies: States and Metropolitan Regions	Timothy Henke	2007	2008
D2036	Highway Research and Technology International Information Sharing	Mukhtar Thakur	1993	Ongoing
D2059	Surface Transportation Security Research	Mark Wikelius	2002	Ongoing
D2068	U.S. Domestic Scan Program Pilot	Randy Halvorson	2006	2008
D2082	Next Generation Transportation Pooled Fund (TPF) Website	Sue Lodahl	2008	2011
D2109	Intelligent Soil Compaction Systems	John Siekmeier	2006	2009
D2431	LRFD Design Specifications for Shallow Foundations	Richard Lamb	2007	2009
D2432	Scour at Wide Piers and Long Skewed Piers	Andrea Hendrickson	2007	2009
D2433	Development of Design Methods for In-Stream Flow Control Structures	Petronella DeWall	Pending	Pending

2008 Active SHRP2 Projects with Mn/DOT Panel Membership

Project Number	Project Title	Mn/DOT Panel Member	Start Date	End Date
FB018	Technical Expert Task Group on Railroad-DOT Institutional Mitigation Strategies	Susan Aylesworth	2008	2010
FB026	Technical Expert Task Group on Guide for the Process of Managing Risk on Rapid Renewal Contracts	Jay Hietpas	2008	2010



Minnesota Department of Transportation

RESEARCH SERVICES 2008 At-A-Glance

This publication provides a guide to the Minnesota Department of Transportation's 2008 research activities. It includes a graphical account of progress on all 2008 active research projects, a list of reports and research implementation products completed in 2008, a list of multi-state pooled fund projects that Mn/ DOT participates in and the following list of strategic research areas that will guide Mn/DOT research over the coming years.

MN/DOT 2009 STRATEGIC DIRECTION FOR RESEARCH

1. Provide a multi-modal infrastructure

- Freight
- Truck size and weight
- Commerce direction vs. transportation industry needs
- Effect of de-icing chemicals on vehicles and electronic components: railroad crossings/freight

2. Organization transformation

- Impact of changing demographics/work force
- Change of customer expectations/needs: innovative contracting/quality assurance
- Growing needs and shrinking resources: cost-effective strategies to continue delivering program
- Mn/DOT organization structure options: regionalization, centralization

3. Innovative project delivery

- Change of culture: increased use of technology, quality, innovation across the organization
- Civil rights: e-bidding
- Remote sensing possibilities
- Accelerated construction: A + B contracting, lane rental, staged construction vs. road closure, rapid bridge or pavement construction methods, prefabricated construction
- Accelerated project development: speed up planning time, increase public input (aesthetics), define Mn/DOT role
- Synthesis of technological advances in data mining/ information sharing

4. Traffic safety: low-cost options to zero deaths

- Small, local, low-cost measures
- Speed as a component of bare lane
- Bridge anti-icing systems as part of the design process
- Civil rights ADA Title II

5. Infrastructure preservation

- Improve management, lower lifecycle costs
- Cost-effective pavement preservation best practices
- Optimization of recycled materials
- Cumulative bridge overloading
- Preservation of modal infrastructure: transit systems, bike trails infrastructure, pavement, bridges, and roadside assets
- Cheap pavements that don't crack

6. Responding to customers and

stakeholders

- Building public confidence: ensuring agency credibility
- Finance and revenue innovation: corridor agency, private funding, GCA California model, innovative funding sources (private sector, European bonds, etc.), "mileage-based" concept
- Impacts of higher gas prices: Decrease in miles traveled, need for new funding sources
- Transportation infrastructure and economic development
- Improved legislative transportation decision processes

7. Green roads

- Green roads: both construction and maintenance, environmental stewardship, implementing technologies to reduce global warming
- Water management and roadsides: preserve critical roadside/water management infrastructure
- Energy efficiency: best practices for low-cost roadway lighting, hybrid vehicles in the snow fighting fleet, self-supplied/solar energy for road/sign/in-pavement lighting
- Clean water practices: NPDES Phase II permit requirements, long-term maintenance and impacts of environmental Best Management Practices
- Environmental forecasting management systems

8. Congestion management

- Benefit/cost evaluation, low-cost fixes vs. major projects
- A + B contracting
- Design-build
- Demand management: Optimize current road system, congestion pricing
- Optimizing cost-effectiveness of shoulders

Completed Research Reports and Implementation Products, January through October 2008

FUNDING SOURCE KEY

ITSIntelligent Transportation SystemLRRBLocal Road Research Board

- OM Office of Maintenance
- OTST Office of Traffic Safety & Technology

SP&R State Planning & Research (FHWA)

SRP State Research Program

A mark in the "TS?" column indicates that a Technical Summary for this project can be found in the 2008 Annual Report or at http://www.research.dot.state.mn.us/.

Funding Source	Cost	Report Number	Project Title	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
LRRB	\$110,000	2008-08	Development of Improved Test Rolling Methods for Roadway Embankment Construction	University of Minnesota	Andrew Drescher, Joseph Labuz, Bojan Guzina	Tim Andersen	Clark Moe	Х
LRRB	\$108,355	2008-42	INV 849: Study of Environmental Effects of De-Icing Salt on Water Quality in the Twin Cities Metropolitan Area, Minnesota	University of Minnesota	Heinz Stefan, Omid Mohseni	Wayne Sandberg	Becky Lein	Х
LRRB	\$102,000	2008-06	INV 808: Pavement Rehabilitation Selection	University of Minnesota, Mn/DOT Office of Materials	Joseph Labuz, Shongtao Dai	Brad C. Wentz	Dan Warzala	Х
LRRB	\$63,871	2008RIC03	Rural Road Safety Solutions Workshop Materials	SRF Consulting Group, Inc.	Mike Marti	Rick West	Sandy McCully	Х
LRRB	\$62,802	2008-54	INV 822: Crack Sealing and Filling Performance	Mn/DOT Office of Materials	Eddie Johnson	Tom Struve	Shirlee Sherkow	
LRRB	\$60,080	2008-28	INV 836: Design Procedure for Bituminous Stabilized Road Surfaces for Low Volume Roads	Minnesota State University, Mankato	James Wilde	Roger Olson, Al Forsberg	Debra Fick	Х
LRRB	\$56,000	MnPAVE08	INV 828: Local Road Material Properties and Calibration of MnPAVE	Mn/DOT Office of Materials	Bruce Chadbourn	Jerry Geib	Dan Warzala	
LRRB	\$52,500	2008-20	Best Practices Handbook for Roadside Vegetation Management	Minnesota State University, Mankato	John Krenz	Paul Walvatne, John McDonald	Debra Fick	Х
LRRB	\$43,257	2008-50	INV 841: Long Term Maintenance Effects on HMA Pavements Caused by Rumble Strips and Available Preventive Treatment Methods	Mn/DOT Office of Materials	Roger Olson	Dennis Luebbe	Dan Warzala	
LRRB	\$39,444	2008-24	INV 839: Toolbox to Evaluate the Impacts of Roundabouts on a Corridor or Roadway Network	lowa State University	Shauna Hallmark	Paul Stine	Clark Moe	Х
LRRB	\$31,450	2008-32	INV 823: The Road to a Thoughtful Street Tree Master Plan	University of Minnesota	Gary Johnson	Daniel Gullickson	Debra Fick	
LRRB	\$30,000	2008-02	INV 838: Evaluation of Paving Fabrics for Isolation of Bituminous Cracking	Red Lake County	Courtney Kleven	Roger Olson, Lou Tasa	Alan Rindels	Х
LRRB	\$25,126	2008-03	INV 827: Investigation of Winter Pavement Tenting	Mn/DOT Office of Materials	Eddie Johnson	Tom Struve, Gary Bruggeman	Dan Warzala	Х
LRRB	\$21,493	2008RIC06	Resource for Implementing a Street Sweeping Best Practice	SRF Consulting Group, Inc.	Mike Marti, Joel Schilling	Tom Colbert	Sandy McCully	Х
LRRB	\$19,422	2008RIC04	Training Module for Pavement Rehabilitation Selection	SRF Consulting Group, Inc.	Mike Marti	Michael Sheehan	Clark Moe	Х
LRRB	\$19,400	2008RIC08	Bridge Management Tool Phase I	Bonestroo, inc.	Matt Shands	Petra DeWall, Tom Behm	Clark Moe	Х
LRRB/SRP	\$226,000	2008-16	INV 817: Determination of Optimum Time for the Application of Surface Treatments to Asphalt Concrete Pavements - Phase II	University of Minnesota, Mn/DOT Office of Materials	Mihai Marasteanu, Timothy Clyne, Heinz Stefan	Roger Olson	Dan Warzala	
LRRB/SRP	\$89,000	2008-35	INV 833: Design Tool for Controlling Runoff and Sediment from Highway Construction	University of Minnesota	Bruce Wilson	Brett Troyer	Dan Warzala	Х
LRRB/SRP	\$79,493	2008-23	INV 857: Effects of Seasonal Changes on Ride Quality at MnROAD	University of Minnesota	Lev Khazanovich	Ben Worel	Cory Johnson	Х
LRRB/SRP	\$71,000	2008-25	Warrants for Right-Turn Lanes/Treatments on Two-Lane Roads	North Dakota State University	Amiy Varma	Brian Gage	Nelson Cruz	Х
LRRB/SRP	\$5,175	TRS0801	INV: 881: Transportation Research Synthesis - Traffic Calming for High-Speed Rural Roadways	Darlene Gorrill	Darlene Gorrill	Sue Lodahl	Sandy McCully	

Completed Research Reports and Implementation Products, cont.

Funding Source	Cost	Report Number	Project Title	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
SRP	\$264,000	2008-51	Self Compacting Concrete (SCC) for Prestressed Bridge Girders	University of Minnesota	Carol Shield	Erik Wolhowe	Dan Warzala	Х
SRP	\$190,777	2008-41	Monitoring and Analysis of Mn/DOT Precast Composite Slab Span System (PCSSS)	University of Minnesota	Cathy French, Carol Shield	Keith Molnau	Alan Rindels	Х
SRP	\$178,524	2008-01	Compaction Remediation for Construction Sites	University of Minnesota	Jonathan Chaplin	Dwayne L. Stenlund	Cory Johnson	Х
SRP	\$167,886	2008-14	Turn Lane Lengths for Various Speed Roads and Evaluation of Determining Criteria	University of Iowa	Tom Schnell, Fuat Aktan	Glen Ellis	Nelson Cruz	Х
SRP/OM	\$146,000	2008-21	Development of a Trash Harvester for Mn/DOT - Phase II	University of Minnesota	Jonathan Chaplin	DeWayne Jones	Sue Lodahl	Х
SRP	\$103,375	2008-48	Improved Methodologies for the Inoculation of Prairie Legumes in Roadside/Revegetation Settings	University of Minnesota	Peter Graham	Kenneth Graeve	Dan Warzala	Х
SRP	\$99,132	2008-49	The Wildlife Value of Reed Canarygrass Infested Wetlands in Min- nesota	Minnesota State University, Mankato	Brock McMillan, Bradley Cook	Kenneth Graeve	Dan Warzala	Х
SRP	\$98,179	2008-04	Wet Meadow Revegetation Following Invasive Plant Control	University of Minnesota	Susan Galatowitsch	Sarma Straumanis, Greg Larson, Dan Shaw	Debra Fick	
SRP	\$96,000	2008-10	Pavement Evaluation Using Ground Penetrating Radar	University of Minnesota	Bojan Guzina	Shongtao Dai	Dan Warzala	Х
SRP	\$88,244	2008-40	Best-Value Based on Performance	North Dakota State University	Magdy Abdelrahman	Jay Hietpas	Nelson Cruz	
SRP	\$88,000	2008-39	Production and Wind Dispersal of Canada Thistle (Cirsium arvense L.) Achenes	University of Minnesota	Roger Becker	Donald Wyse, Tina Markeson	Dan Warzala	Х
SRP	\$69,000	2008-12	Development of Measurement Sources for Freight Performance Indicators	North Dakota State University	Amiy Varma	Robert Gale	Nelson Cruz	Х
SRP	\$59,288	2008-47	Corrosion Protection Performance of Epoxy - Coated Reinforcing Bars	University of Wisconsin- Madison	Jose Pincheria	Paul Rowekamp	Debra Fick	Х
SRP	\$56,802	2008-37	Developing and Implementing Enhanced Pavement Marking Management Tools for Mn/DOT: Phase I - Mapping Tool	lowa State University	Neal Hawkins	Jon Jackels	Alan Rindels	Х
SRP	\$55,508	2008-11	Access to Destinations: How Close is Close Enough? Estimating Accurate Distance Decay Functions for Multiple Modes and Different Purposes	University of Minnesota	Kevin Krizek, Ahmed El-Geneidy	Darryl Anderson	Sue Lodahl	
SRP	\$55,000	2008-09	Improving Capacity Planning for Demand-Responsive Paratransit Services	University of Minnesota	Diwakar Gupta	Sarah Lenz	Alan Rindels	Х
SRP/ITS	\$55,000	2008-17	Cross Median Crashes: Identification and Countermeasures	University of Minnesota	Gary Davis	Dave Engstrom	Dan Warzala	Х
SRP	\$54,046	2008-13	Methods to Incorporate Historic Surface Hydrology Layer in Mn/Model [Phase 4] Using Existing Geographic Information System Data	University of Minnesota	Stacey Stark	Elizabeth Hobbs	Nelson Cruz	Х
SRP	\$50,000	2008-33	The Impact of Bicycling Facilities on Commute Mode Share	University of Minnesota	Frank Douma	Darryl Anderson	Dan Warzala	Х
SRP	\$50,000	2008-36	Generational Perspective on Teen and Older Drivers on Traffic Safety in Rural and Urban Communities	University of Minnesota	Michael Manser, Nic Ward	Gordy Pehrson	Shirlee Sherkow	Х
SRP	\$49,584	2008-26	Access to Destinations: Monitoring Land Use Activity Changes in the Twin Cities Metropolitan Region	University of Minnesota	David Levinson, Ahmed El-Geneidy	Robb Luckow, Rabinder Bains	Sue Lodahl	
SRP	\$38,003	2008-19	Access to Destinations: Parcel Level Land Use Data Acquisition and Analysis for Measuring Non-Auto Accessibility	University of Minnesota	Kevin Krizek, Ahmed El-Geneidy	Robb Luckow, Rabinder Bains	Sue Lodahl	
SRP	\$35,000	2008-15	Access to Destinations: Twin Cities Metro-wide Traffic Micro-simula- tion Feasibility Investigation	University of Minnesota	Panos Michalopoulos, John Hourdos	Robert Byers, Brian Isaacson	Sue Lodahl	
SRP	\$32,283	2008-05	An Inventory of the Public Land Survey Records for Minnesota: The Special Instructions	University of Minnesota	Rod Squires	Jay Krafthefer	Sandy McCully	Х

Completed Research Reports and Implementation Products, cont.

Funding Source	Cost	Report Number	Project Title	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
SRP	\$29,979	BIKEPED08	IMP2006 #2: Promoting the Bicycle and Pedestrian Toolbox	Bonestroo, Rosne, Anderlik & Assoc., Inc.	Matthew Shands	Mary Jackson	Alan Rindels	
SRP	\$27,568	2008-07	Effects of Center-line Rumble Strips on Non-Conventional Vehicles	St. Cloud State University	Kenneth Miller	Dave Engstrom	Dan Warzala	Х
SRP	\$25,502	2008-29	LED Lighting for Snow Plows and Related Maintenance and Construction Vehicles	St. Cloud State University	Timothy Vogt, Kenneth Miller	Farideh Amiri	Becky Lein	Х
SRP	\$7,990	TRS0802	Methods of Estimating the Economic Impact of Transportation Improvements	University of Minnesota	David Levinson, Michael Iacono	Rabinder Bains, Ron Lambert	Alan Rindels	
SP&R/SRP	\$60,000	2008-22	Intelligent Compaction Implementation: Research Assessment	University of Minnesota	Joseph Labuz, Bojan Guzina, Lev Khazanovich	Rebecca Embacher	Clark Moe	Х
SP&R/SRP	N/A	2008-18	MnROAD Cell 54 - Cell Constructed With Mesabi-Select (Taconite- Overburden) Aggregate: Construction and Early Performance Report	Mn/DOT Office of Mainte- nance	Bernard Izevbekhai, Ryan Rohne	N/A	Sandra McCully	
SP&R/SRP	N/A	2008-46	Evaluation of Concrete Pavement Texturing Practices in Minnesota Using the Wet Weather Accident Evaluation Criterion	Mn/DOT Office of Materials	Bernard Izevbekhai	N/A	N/A	
SP&R/ OTST	\$88,000	2008-27	The Effectiveness and Safety of Traffic and Non-Traffic Related Mes- sages Presented on Changeable Message Signs - Phase II	University of Minnesota	Kathleen Harder, John Bloomfield	Todd Kramascz	Cory Johnson	Х
SP&R	\$498,500	2008-30	Review of New Hampshire's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection Deci- sion Support (IDS)	University of Minnesota	Max Donath, Craig Shankwitz	Ginny Crowson	Debra Fick	
SP&R		2008-31	Review of Nevada's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection Decision Support (IDS)	University of Minnesota	Max Donath, Craig Shankwitz	Ginny Crowson	Debra Fick	
SP&R		2008-52	Review of California's Rural Intersection Crashes: Application of Methodology for Identifying Intersections for Intersection Decision Support (IDS)	University of Minnesota	Max Donath	Ginny Crowson	Debra Fick	
SP&R		2008-53	Overview of Rural Intersection Crashes at Candidate Intersections for the Intersection Decision Support (IDS) System	University of Minnesota	Max Donath	Ginny Crowson	Debra Fick	
SP&R	\$24,805	PEEREX07	MPR-6(002) Financial Peer Exchange	CTC & Associates LLC	Patrick Casey	Sue Lodahl	Carol Wiese	
SP&R	N/A	2008-45	Report of Pavement Surface Characteristics Mini-Rodeo (Mn/DOT Test Data and Data Comparison)	Mn/DOT Office of Materials	Bernard Izevbekhai	N/A	N/A	
ITS/OTST	\$102,313	2008-43	Improving Carsharing and Transit Service with ITS	University of Minnesota	Frank Douma	Kenneth Buckeye	Ann McLellan	Х
N/A	\$0	2008-34	Perceptions of the View from the Road AIMS II: A Statewide Web Survey - Aesthetic Initiative Measurement System Phase II	N/A	Joan Iverson Nassauer, Erik Dayrell, Zhifang Wang	David Levinson	Sandra McCully	
N/A	\$0	2008-38	Access to Destinations: Computation of Travel Time Data for Access to Destinations Study	University of Minnesota Duluth	Taek Kwon	Jim Kranig	Sue Lodahl	
N/A	\$0	2008-44	Safety Effects of Centerline Rumble Strips in Minnesota	Mn/DOT	Marc Briese	N/A	N/A	Х

ABOUT THE MN/DOT RESEARCH SERVICES SECTION

Mn/DOT's Research Services Section (RSS) manages the department's research program. RSS staff identify research needs and coordinate research projects for Mn/DOT and the Local Road Research Board, and coordinate Mn/DOT's involvement in state and national cooperative research programs such as the National Cooperative Highway Research Program and the Transportation Pooled Fund program. Mn/DOT conducts research across a broad range of topics, including materials, construction, operations, maintenance, ITS, freight and the environment. The department contracts with Minnesota and out-of-state universities and consultants to carry out this research.

Go to www.research.dot.state.mn.us to download research reports and products.

FUNDING SOURCE KEY

- ITS Intelligent Transportation System
- LRRB Local Road Research Board
- OES Office of Environmental Services
- OM Office of Maintenance
- OTST Office of Traffic Safety & Technology
- SP&R State Planning & Research (FHWA)
- SRP State Research Program



RESEARCH SERVICES Active Research Projects in 2008



Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2005	2006	2007	2008	2009	2010	2011
LRRB	\$440,500	\$367,083	2006-093R	University of Minnesota	Jim Grothaus	Julie Skallman	Clark Moe	INV 668: CY07 Program LTAP Program FED PROJ 8807(157)					83%		
LRRB	\$440,500	\$146,833	2008-015R	University of Minnesota	Jim Grothaus	Julie Skallman	Sue Lodahl	INV 668: Local Technical Assistance Program (LTAP)						33%	
LRRB	\$200,474	\$91,677	2006-080C, Task #16	Pro-West & Associates, Inc.	Annette Theroux	Mark Maloney, Rick Morey	Clark Moe	MPR-6(013): Cadastral And Right of Way Data Exchange - R/W Sharing						75%	
LRRB	\$186,735	\$116,657	2005-010R	University of Minnesota	John Nieber	Stephen Schneider, Andrew Eller	Nelson Cruz	INV 830: Evaluating Roadway Subsurface Drainage Practices					38%	5	
LRRB	\$170,055	\$35,712	2006-010R	University of Minnesota	Paul Bloom	Fred Salsbury	Alan Rindels	INV 847: Use of Fly Ash for Reconstruction of Bituminous Road					13%		
LRRB	\$155,225	\$54,648	2006-009R	University of Minnesota	Satish Gupta	John Siekmeier	Nelson Cruz	INV 846: Hydraulic, Mechanical, and Leaching Characteristics of Recycled Materials						38%	
LRRB	\$139,094	\$35,943	2006-007R	Minnesota State University, Mankato	James Wilde	Tim Stahl	Clark Moe	INV 844: Update of Vehicle Classification for County Road Pavement Design						40%	
LRRB	\$126,042	\$26,280	2006-014R	University of Minnesota	Lev Khazanovich	Jerry Geib	Clark Moe	INV 851: Allowable Axle Loads on Pavements						29%	
LRRB	\$123,000	\$0	2007-005R	University of Minnesota	Omid Mohseni	Mike Eastling	Shirlee Sherkow	INV 874: Assessment of the Underground Stormwater Management Devices Under High Flow Conditions						33%)
LRRB	\$118,908	\$107,017	2006-011R	University of Minnesota	Thomas Smith	Deb Bloom	Dan Warzala	INV 848: Warning Efficacy of Active Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Cross-Walks				_	80%		
LRRB	\$105,000	\$94,500	2006-013R	University of Minnesota	Kimberly Hill	Lee Amundson	Nelson Cruz	INV 850: Mechanistic Modeling of Dynamic Cone Penetrometer Test						67%	
LRRB	\$101,621	\$38,757	2005-022R	North Dakota State University	Magdy Abdelrahman	Tim Andersen	Nelson Cruz	INV 831: Investigation of Stripping in MN Class7 (RAP) and Full Depth Reclamation Base Material					50%	5	
LRRB	\$100,000	\$57,872	2005-011P	Mn/DOT Office of Materials	Robert Edstrom	Ronald Mortensen	Dan Warzala	INV 773-3: Shredded Tires Used for Road Bases; Part 2, Environmental Services Analysis of Samples					95%		

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2005	2006	2007	2008 2009	9 2010	2011
LRRB	\$99,940	\$0	2007-008R	University of Minnesota - Duluth	Taek Kwon	Brian Boder	Alan Rindels	INV 877: Advanced Dynamic LED Warning Signs for Rural Intersections Powered by Renewable Energy						10%
LRRB	\$94,876	\$26,565	2007-002R	University of Minnesota	Diwakar Gupta	Jay Hietpas, Tom Ravn	Alan Rindels	INV 871: Statistical Methods for Materials Testing					20	0%
LRRB	\$92,624	\$32,850	2006-037C	North Dakota State University	Magdy Abdelrahman	Gary Bruggeman	Dan Warzala	INV 855: A Property-Based Specification for Coarse Aggregate in Pavement Applications					43%	
LRRB	\$90,000	\$0	2008-040C	University of Minnesota	Jim Grothaus	Marcus Hall	Clark Moe	INV 998: FY2009 Operational Research Program for Local Transportation Groups OPERA					0	%
LRRB	\$82,400	\$17,200	2007-009P	Mn/DOT Office of Materials	Matthew Lebens	Larry Matsumoto	Bruce Holdhusen	INV 878: Porous Asphalt Pavement Performance in Cold Regions.						38%
LRRB	\$77,905	\$23,372	2006-039R	University of Minnesota	Mihai Marasteanu	John Garrity	Dan Warzala	INV 856: Investigation of In-Place Asphalt Film Thickness and Performance of Minnesota Hot Mix Asphalt Mixtures					33%	
LRRB	\$75,000	\$61,172	2006-005P	Mn/DOT Office of Materials	Eddie Johnson	John P. McDonald	Alan Rindels	INV 842: Best Practices for Dust Control on Aggregate Surfaced Roads					75%	
LRRB	\$75,000	\$56,250	2006-029R	University of Minnesota	Arturo Schultz	Gary Peterson	Nelson Cruz	INV 858: Crack and Concrete Deck Sealant Performance					60%	
LRRB	\$75,000	\$35,500	2008-038C	University of Minnesota	Laurie McGinnis	Julie Skallman	Sue Lodahl	INV 869: TERRA Board Support - FY2009					40%	
LRRB	\$71,638	\$40,678	2006-016C	University of Minnesota	John Nieber	Dan Sauve	Alan Rindels	INV 852: Subsurface Drainage Manual for Pavements in Minnesota					56%	
LRRB	\$71,050	\$10,493	2006-097P	Mn/DOT Office of Materials	Roger Olson	Tim Stahl	Shirlee Sherkow	INV 861: Best Management Practices for Pavement Preservation of Hot Mix Asphalt.					25%	
LRRB	\$70,500	\$60,561	2006-096P	Mn/DOT Office of Materials	John Siekmeier	Larry Berkland	Shirlee Sherkow	INV 860: Compaction Specifications for Unbound Materials				5	50%	
LRRB	\$70,007	\$0	2006-107C, Task #11	SRF Consulting Group, Inc.	Michael Marti	Rich Sanders	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Pavement Management Systems					50%	
LRRB	\$70,000	\$38,500	2006-060R	University of Minnesota	Henry Liu	Eric Drager	Shirlee Sherkow	INV 862: Real Time Arterial Performance				57%	6	
LRRB	\$56,200	\$13,600	2006-003P	Mn/DOT Office of Materials	Shongtao Dai	Brian Noetzelman	Dan Warzala	INV 840-1: Performance of PG 52-34 Oil on Local Roads						33%
LRRB	\$55,000	\$7,975	2007-006R	University of Minnesota	John Gulliver	Rhonda Rae	Shirlee Sherkow	INV 875: Estimating the Size Distribution of Suspended Sediments in Minnesota Stormwater- Phase I: The Methodology						33%
LRRB	\$54,495	\$0	2006-107C, Task #13	SRF Consulting Group, Inc.	Michael Marti	Gary Danielson	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Guardrail and End Treatment Synthesis					10%	
LRRB	\$53,569	\$0	2007-007P	Mn/DOT Office of Materials	Roger Olson	Doug Schwartz	Shirlee Sherkow	INV 876: Best Preventative Maintenance Treatments for Recreational Trails					25%	
LRRB	\$52,980	\$7,947	2006-015R	University of Minnesota - Duluth	Brian Brashaw	Chris Morris	Debra Fick	INV 853: Development of Flexural Vibration Inspection Equipment, Techniques to Assess Structural Health of Rural Bridge Systems II					60%	
LRRB	\$50,663	\$0	2007-001R	University of Minnesota	John Nieber	Alan Forsberg, Susan Miller	Alan Rindels	INV 870: Cost Analysis of Alternative Culvert Installation Practices in Minnesota					33%	

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2005	2006 2007 <mark>2008</mark> 2009 2010 2011
LRRB	\$50,000	\$0	2007-022P	Mn/DOT Office of Materials	Bernard Izevbekhai	Mark Maloney	Bruce Holdhusen	INV 879: Pervious Concrete Pavement in Mn/ROAD Low Volume Road		29%
LRRB	\$46,035	\$45,766	2005-034C	SRF Consulting Group, Inc.	Michael Marti	Julie Skallman	Sandy McCully	INV 999: LRRB Outreach/Communication Activities		83%
LRRB	\$45,400	\$0	2006-042R	University of Minnesota	Craig Shankwitz	Glen Ellis	Shirlee Sherkow	INV 845: Analysis of Highway Design and Geometric Effects on Crashes - Part II		20%
LRRB	\$45,000	\$15,000	2007-041R	St. Louis County	Diwakar Gupta	Marcus Hall	Alan Rindels	INV 880: Snow Plow Optimization		33%
LRRB	\$40,000	\$16,000	2005-005P	Mn/DOT Office of Materials	Shongtao Dai	Michael Sheehan	Alan Rindels	INV 825: Performance Monitoring of Olmsted CR 117/104 and Aggregate Base Material Update		29%
LRRB	\$31,997	\$0	2006-107C, Task #12	SRF Consulting Group, Inc.	Michael Marti	Mark Maloney	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Stormwater BMP Maintenance		75%
LRRB	\$31,040	\$17,313	2006-006R	Minnesota State University, Mankato	James Wilde	John Brunkhorst	Clark Moe	INV 843-1: Predicting the Occurrence of Bumps in Overlays		50%
LRRB	\$30,789	\$5,770	2005-006P	Mn/DOT Office of Materials	Eddie Johnson	John Brunkhorst, David Linell	Clark Moe	INV 826: Appropriate Use of RAP		40%
LRRB	\$30,000	\$19,000	2001-019P	Mn/DOT Office of Materials	Timothy Clyne	Lou Tasa	Dan Warzala	INV 768: Geosynthetics in Roadway Design		70%
LRRB	\$25,564	\$21,730	2006-107C, Task #2	SRF Consulting Group, Inc.	Michael Marti	Tom Behm	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Innovative Contracting Methods for Local Agencies		85%
LRRB	\$20,000	\$7,000	2007-004P	Mn/DOT Office of Materials	Roger Olson	Mark Maloney	Sandy McCully	INV 873: Use of Foamed Asphalt Base Reclamation on Local Roads		71%
LRRB	\$18,950	\$7,250	2007-092C	MIS Sciences Corp	Jeff Willis	Sue Lodahl	Jake Akervik	Research Services and Local Road Research Board Web Site Hosting and Maintenance 2008 - 2009		42%
LRRB	\$7,938	\$7,938	2007-066C	Athey Creek Consultants, LLC	Dean Deeter	Sue Lodahl	Nelson Cruz	INV 884: Redesign of Local Road Research Board (LRRB) Website		100%
LRRB/ SP&R	\$300,000	\$0	2006-088R	Mn/DOT Office of Materials	Timothy Clyne	Greg Johnson	Bruce Holdhusen	INV 868: MPR-6(029): HMA Surface Characteristics.		0%
LRRB/ SP&R	\$200,000	\$0	2006-099P	Mn/DOT Office of Materials	Eddie Johnson	Greg Johnson	Bruce Holdhusen	INV 864: MPR-6(022): Recycled Asphalt Pavements.		11%
LRRB/SRP	\$292,385	\$169,385	2003-075R	University of Minnesota	Lev Khazanovich	Jerry Geib	Dan Warzala	INV 815: Calibration of the 2002 AASHTO Pavement Design Guide for MN PCC/HMA Pavements		55%
LRRB/SRP	\$98,715	\$50,456	2007-070C	CH2M Hill	Howard Preston	Glen Ellis	Shirlee Sherkow	INV 845: Analysis of Highway Design and Geometric Effects on Crashes - Part I		25%
LRRB/SRP	\$50,000	\$0	2008-051C	University of Minnesota	Gina Baas	Sue Lodahl	Sandy McCully	RSS Report Publication Services, 2009		50%
LRRB/SRP	\$17,910	\$9,945	2007-018C	Darlene Gorrill	Darlene Gorrill	Sue Lodahl	Sandy McCully	INV 881: LRRB Annual Program/Technical Research Synthesis Reports		50%
LRRB/ SRP/SP&R	\$63,500	\$0	2007-003R	University of Minnesota	Randal Barnes	Thomas Burnham	Shirlee Sherkow	INV 872: Mn/Road Data Mining, Evaluation and Qualification Phase 1		20%

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Tech Liaison	Admin Liaison	Project Title	2005	2006	2007	2008	2009 2	2010	2011
SRP	\$200,502	\$9,023	2008-021R	University of Minnesota	David Levinson	Rabinder Bains	Alan Rindels	Traffic Flow, Road User Impacts of the Collapse of the I-35W Bridge Over the Mississippi River							17%
SRP	\$186,000	\$0	2008-009R	University of Minnesota	David Levinson	Paul Czech	Sue Lodahl	Access to Destinations Phase 3: Measuring Accessibility by Automobile						0%	,
SRP	\$186,000	\$0	2008-009R	University of Minnesota	David Levinson	Paul Czech	Sue Lodahl	Access to Destinations Phase 3: Measuring Accessibility by Automobile						0%	2
SRP	\$184,000	\$90,000	2007-023R	University of Minnesota	Robert Johns	Darryl Anderson, Robb Luckow	Sue Lodahl	Access to Destinations: Application of Accessibility Measures for Non-Auto Travel Modes					33	%	
SRP	\$160,000	\$0	2007-028R	University of Minnesota	Rajesh Rajamani	Gabe Guevara	Dan Warzala	Automated Vehicle Location, Data Recording and Applicator Control for Winter Road Maintenance						9%	
SRP	\$160,000	\$0	2008-005R	University of Minnesota	Omid Mohseni	Barbara Loida	Shirlee Sherkow	Assessment and Recommendation for Operation of Standard Sumps as Best Management Practices for Stormwater Treatment			0%				l
SRP	\$158,872	\$4,846	2007-034R	University of Minnesota	John Nieber	Kenneth Graeve	Shirlee Sherkow	Wetlands: Role of Buffers in Upland Infiltration, Nutrient Absorption, and Wildlife Habitat						11%	
SRP	\$153,900	\$40,356	2007-030R	Minnesota State University, Mankato	Aaron Budge	Gary Person	Nelson Cruz	Development of a Resistance Factor for Mn/DOT's Pile Driving formula and Study of Pile Setup Evaluation Methods						25%	
SRP	\$150,000	\$58,500	2006-041R	University of Minnesota	Henry Liu	Ernest Lloyd	Cory Johnson	Responding to the Unexpected Development of a Dynamic Data - Driven Traffic Operation Model for Effective Evacuation					38%		
SRP	\$150,000	\$15,000	2006-111R	University of Minnesota	Gary Davis	Gene Hicks	Sue Lodahl	Access to Destinations: Arterial Data Acquisition and Network-Wide Travel Time Estimation (Phase II)					13	%	
SRP	\$150,000	\$0	2006-121C	University of Minnesota	John Hourdos	Colleen VanWagner	Bruce Holdhusen	MPR-6(003):TH36 Full Closure Impacts - Highways for Life Corridor					25%	6	
SRP	\$150,000	\$0	2008-007R	University of Illinois	Erol Tutumluer	John Siekmeier	Nelson Cruz	Best Value Granular Material for Road Foundations							0%
SRP	\$140,000	\$74,000	2007-049R	University of Minnesota	Jim Grothaus	Scott Bradley	Clark Moe	MPR 6(007): Hear Every Voice (HEV) Implementation & Training					, (50%	
SRP	\$125,160	\$15,019	2008-003R	University of Minnesota	Arturo Schultz	Gary Peterson, Todd Nieman	Shirlee Sherkow	Bridge Health Monitoring and Inspection - A Survey of Methods					11	%	
SRP	\$114,390	\$30,885	2006-030R	University of Minnesota	Cathy French	Lowell Johnson	Shirlee Sherkow	Discrepancies in Shear Strength of Prestressed Beams with Different Specifications					20	1%	
SRP	\$109,890	\$43,407	2007-063C	University of Minnesota	John Hourdos	Chris Roy, Colleen VanWagner	Bruce Holdhusen	MPR-6(009): TH36 Full Closure Impacts - Highways for Life corridor. To Close or Not to Close					36	1%	
SRP	\$109,562	\$71,215	2006-027R	University of Minnesota - Duluth	Kurt Johnson	Sarma Straumanis	Debra Fick	Wetland Mitigation in Abandoned Gravel Pits						67%	ó
SRP	\$99,953	\$44,109	2007-065C	CNA Consulting Engineers, Inc.	Charles Nelson	Tim Anderson, Rebecca Embacher	Clark Moe	MPR-6(011): Intelligent Compaction Implementation: IC Data Management					28%		
SRP	\$99,032	\$99,032	2008-024C	HNTB Corporation	Richard Stehr	Bruce Holdhusen	Bruce Holdhusen	Mn/DOT Research and Innovation Roadmap Build-out - HNTB				100)%		
SRP	\$98,769	\$98,769	2008-023C	SRF Consulting Group, Inc.	Michael Marti	Bruce Holdhusen	Bruce Holdhusen	Research and Innovation Roadmap Build-out: Multi-Modal Infrastructure (Freight) Congestion Management				100	1%		

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Tech Liaison	Admin Liaison	Project Title	2005	2006	2007 2008	2009 20	10 2011
SRP	\$98,173	\$98,173	2008-028C	EVS	Paul Keranen	Bruce Holdhusen	Bruce Holdhusen	Research and Innovation Roadmap Build-Out - EVS				00%	
SRP	\$91,388	\$49,350	2006-047R	University of Minnesota - Duluth	Taek Kwon	Matthew Oman	Nelson Cruz	Development of Data Warehouse and Application for Continuous Vehicle Class and Weigh-in-Motion (WIM) Data				50%	
SRP	\$88,244	\$84,000	2005-015R	North Dakota State University	Magdy Abdelrahman	Jay Hietpas	Nelson Cruz	Best Value Based on Performance				86%	
SRP	\$79,937	\$14,747	2006-032R	Minnesota State University, Mankato	John Krenz	Jason Alcott	Dan Warzala	The Utility of Wildlife Crossings in Minnesota					33%
SRP	\$76,000	\$32,000	2007-035R	University of Minnesota	Nikos Papanikolopoulos	Darryl Anderson	Alan Rindels	Analysis of Practical Methods for Counting Bicycling and Pedestrian Use of a Transportation Facility				209	%
SRP	\$75,000	\$67,687	2006-048C	North Dakota State University	Amiy Varma	Gene Hicks	Nelson Cruz	Feasibility of Statewide Travel Demand Model				93%	
SRP	\$72,637	\$7,990	2007-029R	University of Minnesota	David Levinson	Rabinder Bains, Ron Lambert	Alan Rindels	Economic Impact of Upgrading Roads				20%)
SRP	\$70,000	\$14,000	2006-044R	University of Minnesota	Henry Liu	Sue Zarling	Shirlee Sherkow	Development of a Platoon-Priority Control Strategy with/out Advance Warning Flasher for Isolated High-Speed Intersection				50%	
SRP	\$65,000	\$20,000	2006-034C	University of Minnesota	Adeel Lari	Rabinder Bains	Dan Warzala	Developing a Decision-Making Model for Advanced Acquisition				20%	
SRP	\$60,000	\$0	2008-004R	University of Minnesota	Jeff Marr	Andrea Hendrickson	Shirlee Sherkow	Evaluation & Recommendation of Bridge Scour Depth Monitoring Technologies for Safety Evaluation & Monitoring of River Bridges in Minnesota			L		0%
SRP	\$55,000	\$0	2008-008R	University of Minnesota	Vladimir Cherkassky	Robert Edstrom	Dan Warzala	Statistical Analysis of the Soil Chemical Survey Data					0%
SRP	\$51,832	\$0	2007-033R	University of Minnesota	David Levinson	Gene Hicks	Shirlee Sherkow	Post-Construction Evaluation of Forecast Accuracy				16%)
SRP	\$43,000	\$0	2007-082C	Minnesota State University, Mankato	James Wilde	Tom Nordstrom	Bruce Holdhusen	MPR-6(035): Contractor Certification Program for the Mn/DOT International Roughness Index (IRI) Specification					50%
SRP	\$35,000	\$17,500	2006-076C	Campbell Scientific	Jim Bilskie	John Siekmeier	Bruce Holdhusen	IMP2006 #1: Portable Field Moisture Technology				50%	
SRP	\$34,997	\$0	2006-078C	American Engineering Testing Inc.	Dave Rettner	Bernard Izevbekhai	Bruce Holdhusen	IMP2006 #4: Implementation of the Hydraulic Fracture Test Specification for Coarse Aggregate				30%	
SRP	\$25,362	\$0	2008-088C	CH2M Hill	Nicole Farrington	Colleen VanWagner	Bruce Holdhusen	MPR-6(009): Cost Estimate Study of Partial Closure of TH 36				0%	
SRP	\$21,076	\$21,076	2006-109C	CTC & Associates LLC	Patrick Casey	Sandy McCully	Sandy McCully	Minnesota TRB Guide and RSS Calendar for 2007 & 2008			1009	6	
SRP	\$14,000	\$1,750	2008-014C	University of Minnesota	Gina Baas	Sue Lodahl	Sue Lodahl	Access to Destinations Study, Administration 2008-2009					13%
SRP	\$6,117	\$0	2008-062C	Bonestroo, Rosene, Anderlik & Assoc., Inc	Matthew Shands	Paul Kauppi	Shirlee Sherkow	Stormwater Infiltration Systems TRS				0%	
SRP/OM	\$20,270	\$8,628	2007-083C	University of Minnesota	John Nieber	Paul Walvatne	Shirlee Sherkow	IMP2006: Implementation of a Survey Method for Noxious Weeds				50%	

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Tech Liaison	Admin Liaison	Project Title	2005	2006	2007	2008 20	09 2010	0 2011
SRP/ SP&R	\$425,000	\$305,000	2007-054R	Iowa State University	David White	John Siekmeier	Clark Moe	MPR-6(011): Implementation of Intelligent Compaction Performance Based Specifications in Minnesota - Iowa State					50%	
SRP/ SP&R	\$238,000	\$73,780	2007-025C	HHH Institute of Public Affairs	Lee Munnich	Kenneth Buckeye	Ann McLellan	Innovative Parking Pricing Demonstration Project					3	1%
SRP/ SP&R	\$209,000	\$76,000	2007-039C	Archwing Innovations LLC	Ryan Anderson	Cory Johnson	Ann McLellan	MPR-6(005): Research Management System-Phase I					10%	
SRP/ SP&R	\$99,981	\$81,393	2007-064C	Professional Engineering Services Ltd.	Ann Johnson	Tim Andersen	Clark Moe	MPR-6(011): Intelligent Compaction Implementation: Training and Field Support				98%		
SRP/ SP&R	\$99,203	\$89,806	2007-075C	CTC & Associates LLC	Patrick Casey	Cory Johnson	Sandy McCully	MPR-6(019): Technology Transfer Material Development				1	00%	
SRP/ SP&R	\$83,490	\$26,978	2007-060C	William Bunde	Bill Bunde	Cory Johnson	Clark Moe	MPR-6(004): Investigation & Evaluation of Close Out Memo Data for the Development of Additional Performance Measures					3	35%
SRP/ SP&R	\$39,600	\$6,545	2007-102C	Darlene Gorrill	Darlene Gorrill	Jake Akervik	Clark Moe	MPR-6(004): Implementation plan Development, Closeout Memos, and Implementation Communication Products					16%	
SRP/ SP&R	\$35,630	\$3,563	2007-084C	University of Minnesota	Arturo Schultz	Jim Pierce	Bruce Holdhusen	MPR-6(036): Implementation of Steel Bridge Maintenance Planning					25%	
SRP/ SP&R	\$35,400	\$0	2007-032R	University of Minnesota - Duluth	John Evans	Farideh Amiri	Bruce Holdhusen	MPR-6(014): Evaluation of SafeLane Overlay System for Crash Reduction on Bridge Deck Surfaces Years 2 & 3						60%
SP&R	\$253,300	\$0	2006-120C	Minnesota State University, Mankato	Aaron Budge	Tim Anderson, Jay Hietpas	Clark Moe	MPR-6(012): Dev. of New Test Roller Equipment & Construction Specs for Subgrade Compaction Acceptance						40%
SP&R	\$250,000	\$99,555	2007-081C	Project Information Services	Timothy Malagon	Thomas Wiener	Clark Moe	MPR-6(033): Field Evaluation of the Transportation Automated Control System TRACS						40%
SP&R	\$138,697	\$0	2008-048R	Minnesota State University, Mankato	James Wilde	Thomas Wiener	Clark Moe	MPR-6(033): Transportation Automated Control System (TRACS) TRACS Evaluation			0%	6		
SP&R	\$126,100	\$0	2007-094P	Mn/DOT Office of Materials	Thomas Burnham	Bernard Izevbekhai	Bruce Holdhusen	MPR-6(031): Concrete Pavement Optimization, Determining the Lower Threshold of Slab Thickness for High Volume Roadways			25%			
SP&R	\$99,911	\$25,678	2008-032C	CTC & Associates LLC	Patrick Casey	Jake Akervik	Cory Johnson	MPR-6(019): Technology Transfer Material Development - Phase 2				-	80)%
SP&R	\$67,500	\$23,100	2008-043C	Micky Ruiz	Micky Ruiz	Jake Akervik	Clark Moe	MPR-6(004): Implementation & Closeout Program Administration Support					20%	
SP&R	\$37,500	\$33,000	2007-072R	University of North Dakota	Leon Osborne	Todd Kramascz	Debra Fick	North/West Passage Clarus Regional Demonstration, Environmental Sensor Station Metadata Development					50%	
ITS	\$298,000	\$0	2005-058C	University of Minnesota	Lee Munnich	Kenneth Buckeye	Ann McLellan	I-394 MnPASS Outreach and Education					61%	
OES	\$15,800	\$0	2008-078R	University of Minnesota	John Nieber	Paul Walvatne	Shirlee Sherkow	Implementation of Methodology for Weed Management Practices - Phase II					0%	
OTST	\$43,966	\$43,966	2006-072R	University of Minnesota	Henry Liu	Sue Sheehan	Ann McLellan	Evaluation of Cell Phone Traffic Data				10	0%	
Legislative Funding	\$200,000	\$0	2008-082R	University of Minnesota	Lee Munnich	Kenneth Buckeye	Kenneth Buckeye	Minnesota Urban Partnership Agreement (UPA)						0%

Active Multi-State Pooled Funds in 2008

Study Number	Mn/DOT Tracking #	Title	Total Project Cost	MN 2008 Commitment	Lead State or Agency	Mn/DOT Contact	Start Date	Projected End Date
SPR-2(207)	2007-172	Transportation Management Center Pooled Fund Study	\$3,166,665	\$0	FHWA	Todd Kramascz	2000	Ongoing
SPR-3(017)	2007-166	Midwest States Pooled Fund Crash Test Program	\$7,384,934	\$56,700	NE	Bernard Izevbekhai	1991	Ongoing
SPR-3(020)	2007-165	IVHS Study (ENTERPRISE)	\$1,170,000	\$30,000	IA	Ray Starr	1995	Ongoing
SPR-3(042)	2007-137	Aurora Program	\$2,572,500	\$25,000	IA	Curt Pape	2003	Ongoing
SPR-3(049)	2007-164	Urban Mobility Study	Over \$1,500,000	\$30,000	ТХ	Paul Czech	1997	Ongoing
SPR-3(072)	2007-133	Strength and Deformation Analysis of MSE Walls at Working Loads	\$730,000	\$0	WA	Blake Nelson	1999	2008
SPR-3(074)	2007-131	Pavement Research and Technology	\$625,000	\$0	WA	Roger Olson	2002	2008
SPR-3(098)	2007-158	Pavement Reconstruction Scheduling Software	\$614,399	\$0	WA	Maureen Jenson	2000	2008
TPF-5(004)	2007-157	Long Term Pavement Performance (LTPP) Specific Pavements Study (SPS) Traffic Data Collection	\$14,676,285	\$35,000	FHWA	George Cepress	2003	2009
TPF-5(029)	2007-156	High Occupancy Vehicle	\$128,859	\$25,000	FHWA	Janelle Anderson	2002	2010
TPF-5(035)	2008-025	Pacific Northwest Snowfighters	\$250,000	\$20,000	WA	Gabe Guevara	2007	2010
TPF-5(036)	2007-155	Transportation Asset Management Research Program	\$960,000	\$7,200	WI	Steve Lund	2002	2008
TPF-5(039)	2007-153	Falling Weight Deflectometer (FWD)	\$815,000	\$0	FHWA	David Bullock	2004	2009
TPF-5(046)	2007-151	Transportation Curriculum Coordination Council Training Management and Development	\$950,000	\$15,000	FHWA	Catherine Betts	2002	2013
TPF-5(051)	2007-150	Construction of Crack-Free Concrete Bridge Decks	\$995,000	\$0	KS	Paul Rowekamp	2002	2008
TPF-5(054)	2007-149	Maintenance Decision Support System (MDSS)	Unknown	\$50,000	SD	Curt Pape	Ongoing	Ongoing
TPF-5(060)	2007-169	Safety Analyst	\$50,000	\$30,000	FHWA	Dave Engstrom	2001	2008
TPF-5(066)	2007-147	Material & Construction Optimization	\$865,000	\$0	IA	Bernard Izevbekhai	2003	2008
TPF-5(068)	2007-125	Long-Term Maintenance of Load and Resistance Factor Design Specifications	\$980,000	\$20,000	IA	Dave Dahlberg	2003	2008
TPF-5(069)	2007-146	Core Program Services for a Highway Research, Development, and Technology Program	\$17,500,000	\$0	FHWA	Sue Lodahl	2004	Ongoing
TPF-5(070)	2009-077	International Conference on Accelerated Pavement Testing	\$130,000	\$0	MN	Ben Worel	2007	2009
TPF-5(086)	2003-066	Reducing Crashes at Rural Intersections: Toward a Multi-State Consensus on Rural Intersection Decision Support	\$4,985,000	\$0	MN	Ginny Crowson	2004	2008
TPF-5(090)	2007-124	Pavement Tools Consortium	\$910,000	\$0	WA	Roger Olson	2000	2008
TPF-5(092)	2007-123	Clear Roads (Test & Evaluation of Materials, Equipment & Methods for Winter Maintenance)	\$905,000	\$25,000	WI	Linda Taylor	2004	Ongoing
TPF-5(093)	2007-175	North/West Passage (Phase III)	\$425,000	\$0	MN	Todd Kramascz	2004	2008
TPF-5(099)	2007-122	Evaluation of Low Cost Safety Improvements	\$2,850,000	\$0	FHWA	Dave Engstrom	2005	2011
TPF-5(105)	2007-121	Transportation Connectivity Pooled Fund	\$20,000	\$0	WI	Sheila Hatchell	2005	2009
TPF-5(106)	2007-145	Guidelines for Designing Bridge Piers and Abutments for Vehicle Collisions	\$430,000	\$0	ТХ	Dave Dahlberg	2007	2009
TPF-5(107)	2007-120	Refinement and Field Validation of Mix Design Criteria for 4.75mm Superpave Mixes	\$195,000	\$0	AL	John Garrity	2005	2008
TPF-5(109)	2007-144	TRB Core Program Services for FY'07	\$17,500,000	\$127,705	FHWA	Sue Lodahl	2007	Ongoing
TPF-5(111)	2007-119	Development of Standards for Geotechnical Management Systems	\$695,000	\$0	OH	Gary Person	2005	2008
TPF-5(111)	2007-119	Development of Standards for Geotechnical Management Systems	\$695,000	\$0	OH	Gary Person	2005	2008
TPF-5(112)	2007-118	Midwest States Pooled Fund Pavement Preservation Partnership	\$195,000	\$0	МІ	Erland Lukanen	2003	2008
TPF-5(114)	2007-117	Roadside Safety Research Program	\$550,000	\$0	WA	Michelle Elle, Nancy Yoo	2005	2009
TPF-5(116)	2007-143	Investigation of the Fatigue Life of Steel Base Plate to Pole Connections for Traffic Structures	\$443,000	\$25,000	ТХ	Thomas Merritt	2005	2009
TPF-5(119)	2007-115	North Central Pavement Research Partnership	\$30,000	\$0	WI	Maureen Jensen	2006	2008

Active Multi-State Pooled Funds in 2008, cont.

Study Number	Mn/DOT Tracking #	Title	Total Project Cost	MN 2008 Commitment	Lead State or Agency	Mn/DOT Contact	Start Date	Projected End Date
TPF-5(120)	2007-114	Deer Vehicle Crash Information and Research (DVCIR) Center Pooled Fund	\$260,000	\$0	FHWA	Robert Weinholzer	2007	2009
TPF-5(126)	2006-024	Geocomposite Capillary Barrier Drain (GCBD) for Limiting Moisture Changes in Pavements: Product Application	\$255,000	\$0	MN	Andrew Eller	2006	2008
TPF-5(127)	2007-113	Consortium of Accelerated Pavement Testing (CAPT) and Technical Exchange Partnership	\$225,000	\$0	FHWA	Ben Worel	2007	2009
TPF-5(128)	2007-112	Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Material	\$725,000	\$5,000	FHWA	Tom Ravn	2007	2010
TPF-5(129)	2008-030	Recycled Unbound Pavement Materials (MnROAD Study)	\$882,352	\$15,000	MN	Ben Worel	2007	2010
TPF-5(132)	2007-093	Investigation of Low Temperature Cracking in Asphalt Pavements - Phase II	\$420,000	\$20,000	MN	Ben Worel	2007	2011
TPF-5(134)	2008-044	PCC Surface Characteristics - Rehabilitation (MnROAD Study)	\$275,000	\$0	MN	Bernard Izevbekhai	2007	2012
TPF-5(135)	2007-058	Tire Pavement Noise Research Consortium	\$150,000	\$0	WA	Bernard Izevbekhai	2006	2011
TPF-5(139)	2007-110	PCC surface Characteristics: Tire-Pavement Noise Program Part III	\$690,000	\$15,000	IA	Bernard Izevbekhai	2005	2010
TPF-5(144)	2007-109	Use of Video Feedback in Urban Teen Drivers	\$160,000	\$40,000	IA	Ray Starr	2007	2008
TPF-5(148)	2008-086	Effects of Implements of Husbandry "Farm Equipment"	\$433,000	\$35,000	MN	Shongtao Dai	2007	2010
TPF-5(149)	2008-002	Design and Construction Guidelines for Thermally Insulated Concrete Pavements (MnROAD Study)	\$455,000	\$20,000	MN	Tim Clyne	2007	2011
TPF-5(153)	2006-101	Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements (MnROAD)	\$335,000	\$15,000	MN	Ben Worel	2007	2012
TPF-5(154)	2007-074	Census Transportation Planning Products (CTPP) from the American Community Survey	\$1,428,704	\$0	FHWA	Jonette Kreideweis	2007	2012
TPF-5(156)	2007-108	Mississippi Valley Freight Coalition Pooled Fund Study	\$425,000	\$25,000	WI	Dave Christianson	2007	2009
TPF-5(159)	2008-026	Technology Transfer Concrete Consortium	\$299,000	\$5,000	IA	Maria Masten	2007	2012
TPF-5(164)	2007-107	Fish Passage in Large Culvert With Low Flows	\$210,000	\$15,000	FHWA	Petra DeWall	2007	2008
TPF-5(165)	2008-050	Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements	\$360,000	\$20,000	MN	Tom Burnham	2007	2011
TPF-5(171)	2007-106	Non-Intrusive Traffic Detection Systems III	\$225,000	\$0	MN	Jerry Kotzenmacher	2007	2009
TPF-5(174)	2008-079	Construction of Crack-Free Bridges - Phase II	\$950,000	\$15,000	KS	Paul Kivisto	2007	2011
TPF-5(179)	2008-052	Evaluation of Test Methods for Permeability (Transport) and Development of Performance Guidelines for Durability	Unknown	\$25,000	IN	Maria Masten	2008	2011
TPF-5(187)	2008-061R	Updating U.S. Precipitation Frequency Estimates for the Midwestern Region	\$1,109,206	\$66,667	FHWA	Andrea Hendrickson	2008	TBD
TPF-5(190)	TBD	Northwest Passage, Phase III	\$200,000	\$25,000	MN	Todd Kramascz	2008	TBD
TPF-5(192)	TBD	Loop and Length Based Classification Pooled Fund	\$365,000	\$15,000	FHWA	Gene Hicks	2008	2009
TPF-5(407)	TBD	National Cooperative Research Program (NCHRP) FY 2007	N/A	\$0	MN	Sue Lodahl	N/A	Ongoing
TPF-5(408)	TBD	National Cooperative Research Program (NCHRP) FY 2008	Unknown	\$597,865	FHWA	Sue Lodahl	2008	New



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This publication provides a guide to the Local Road Research Board's 2008 research activities. It includes a graphical account of progress on all 2008 active research projects, a list of reports and research implementation products completed in 2008 and an overview of LRRB including the following strategic research goals that will guide LRRB research over the coming years.

LRRB MISSION

The mission of the LRRB is to serve local road transportation practitioners through the development of new initiatives, the acquisition and application of new knowledge, and the exploration and implementation of new technologies

LRRB STRATEGIC GOALS

LRRB is focused on research projects that improve Minnesota's local government road system with regard to:

1. Design—

the determination of the need for and nature of a proposed road system project

- 2. Construction the implementation of the plans and specifications from the road system design process
- 3. Maintenance/Operations—

the operation and maintenance of the road system investment

4. Environmental Compatibility—

the integration of the local road system into the community to minimize adverse environmental impacts while contributing to economic and social well-being

About LRRB

Established through Minnesota state legislation in 1959, the Local Road Research Board brings the latest developments in transportation research to the state's city and county engineers. Research applications range from new and more economical ways to recycle pavement to better inspection techniques for bridges.

The 10-member board includes city and county engineers, the State Aid Engineer, the director of the Mn/DOT Office of Materials, a University of Minnesota Center for Transportation Studies representative and the director of Mn/DOT Research Services.

The Research Implementation Committee (http://www.lrrb.org/ric.aspx) is a subgroup of the LRRB. The goal of RIC is to make information available and transfer research results into practical application.

For more information about the projects listed in this publication, search for reports and initiate queries at http://www.lrrb.org/. Our Web site lists LRRB members, provides news and events information, explains more about our mission and plans, and provides links to useful Web-based tools like the Geosynthetic Design Guide, Minnesota Research Test Section Tracking database and Mix Asphalt Design Tool.

FUNDING SOURCE KEY

LRRB Local Road Research Board SP&R State Planning & Research (FHWA) SRP Mn/DOT State Research Program

LRRB RESEARCH Active Research Projects in 2008



Total Cost	Amount Paid	Funding Source	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2005	2006	2007	2008	2009	2010	2011
\$440,500	\$367,083	LRRB	2006-093R	University of Minnesota	Jim Grothaus	Julie Skallman	Clark Moe	INV 668: CY07 Program LTAP Program FED PROJ 8807(157)					83%		
\$440,500	\$146,833	LRRB	2008-015R	University of Minnesota	Jim Grothaus	Julie Skallman	Sue Lodahl	INV 668: Local Technical Assistance Program (LTAP)						33%	
\$300,000	\$0	LRRB/ SP&R	2006-088R	Mn/DOT Office of Materials	Timothy Clyne	Greg Johnson	Bruce Holdhusen	INV 868: MPR-6(029): HMA Surface Characteristics.		09	6				
\$292,385	\$169,385	LRRB/SRP	2003-075R	University of Minnesota	Lev Khazanovich	Jerry Geib	Dan Warzala	INV 815: Calibration of the 2002 AASHTO Pavement Design Guide for MN PCC/HMA Pavements					55%		
\$200,474	\$91,677	LRRB	2006-080C, Task #16	Pro-West & Associates, Inc.	Annette Theroux	Mark Maloney, Rick Morey	Clark Moe	MPR-6(013): Cadastral And Right of Way Data Exchange - R/W Sharing						75%	
\$200,000	\$0	LRRB/ SP&R	2006-099P	Mn/DOT Office of Materials	Eddie Johnson	Greg Johnson	Bruce Holdhusen	INV 864: MPR-6(022): Recycled Asphalt Pavements.			11%				
\$186,735	\$116,657	LRRB	2005-010R	University of Minnesota	John Nieber	Stephen Schneider, Andrew Eller	Nelson Cruz	INV 830: Evaluating Roadway Subsurface Drainage Practices					389	6	
\$170,055	\$35,712	LRRB	2006-010R	University of Minnesota	Paul Bloom	Fred Salsbury	Alan Rindels	INV 847: Use of Fly Ash for Reconstruction of Bituminous Road					139	6	
\$155,225	\$54,648	LRRB	2006-009R	University of Minnesota	Satish Gupta	John Siekmeier	Nelson Cruz	INV 846: Hydraulic, Mechanical, and Leaching Characteristics of Recycled Materials						38%	
\$139,094	\$35,943	LRRB	2006-007R	Minnesota State University, Mankato	James Wilde	Tim Stahl	Clark Moe	INV 844: Update of Vehicle Classification for County Road Pavement Design						40%	
\$126,042	\$26,280	LRRB	2006-014R	University of Minnesota	Lev Khazanovich	Jerry Geib	Clark Moe	INV 851: Allowable Axle Loads on Pavements						29%	
\$123,000	\$0	LRRB	2007-005R	University of Minnesota	Omid Mohseni	Mike Eastling	Shirlee Sherkow	INV 874: Assessment of the Underground Stormwater Management Devices Under High Flow Conditions						33%	
\$118,908	\$107,017	LRRB	2006-011R	University of Minnesota	Thomas Smith	Deb Bloom	Dan Warzala	INV 848: Warning Efficacy of Active Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Cross-Walks					809	6	

Total Cost	Amount Paid	Funding Source	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2005	2006	2007 20	008 20	09 20	010	2011
\$105,000	\$94,500	LRRB	2006-013R	University of Minnesota	Kimberly Hill	Lee Amundson	Nelson Cruz	INV 850: Mechanistic Modeling of Dynamic Cone Penetrometer Test					679	%	
\$101,621	\$38,757	LRRB	2005-022R	North Dakota State University	Magdy Abdelrahman	Tim Andersen	Nelson Cruz	INV 831: Investigation of Stripping in MN Class7 (RAP) and Full Depth Reclamation Base Material					50%		
\$100,000	\$57,872	LRRB	2005-011P	Mn/DOT Office of Materials	Robert Edstrom	Ronald Mortensen	Dan Warzala	INV 773-3: Shredded Tires Used for Road Bases; Part 2, Environmental Services Analysis of Samples				95	5%		
\$99,940	\$0	LRRB	2007-008R	University of Minnesota - Duluth	Taek Kwon	Brian Boder	Alan Rindels	INV 877: Advanced Dynamic LED Warning Signs for Rural Intersections Powered by Renewable Energy							10%
\$98,715	\$50,456	LRRB/SRP	2007-070C	CH2M Hill	Howard Preston	Glen Ellis	Shirlee Sherkow	INV 845: Analysis of Highway Design and Geometric Effects on Crashes - Part I					259	%	
\$94,876	\$26,565	LRRB	2007-002R	University of Minnesota	Diwakar Gupta	Jay Hietpas, Tom Ravn	Alan Rindels	INV 871: Statistical Methods for Materials Testing						20%	
\$92,624	\$32,850	LRRB	2006-037C	North Dakota State University	Magdy Abdelrahman	Gary Bruggeman	Dan Warzala	INV 855: A Property-Based Specification for Coarse Aggregate in Pavement Applications					43	3%	
\$90,000	\$0	LRRB	2008-040C	University of Minnesota	Jim Grothaus	Marcus Hall	Clark Moe	INV 998: FY2009 Operational Research Program for Local Transportation Groups OPERA						0%	
\$82,400	\$17,200	LRRB	2007-009P	Mn/DOT Office of Materials	Matthew Lebens	Larry Matsumoto	Bruce Holdhusen	INV 878: Porous Asphalt Pavement Performance in Cold Regions.			-				38%
\$77,905	\$23,372	LRRB	2006-039R	University of Minnesota	Mihai Marasteanu	John Garrity	Dan Warzala	INV 856: Investigation of In-Place Asphalt Film Thickness and Performance of Minnesota Hot Mix Asphalt Mixtures					339	%	
\$75,000	\$61,172	LRRB	2006-005P	Mn/DOT Office of Materials	Eddie Johnson	John P. McDonald	Alan Rindels	INV 842: Best Practices for Dust Control on Aggregate Surfaced Roads					75%		
\$75,000	\$56,250	LRRB	2006-029R	University of Minnesota	Arturo Schultz	Gary Peterson	Nelson Cruz	INV 858: Crack and Concrete Deck Sealant Performance					60%		
\$75,000	\$35,500	LRRB	2008-038C	University of Minnesota	Laurie McGinnis	Julie Skallman	Sue Lodahl	INV 869: TERRA Board Support - FY2009					4	10%	
\$71,638	\$40,678	LRRB	2006-016C	University of Minnesota	John Nieber	Dan Sauve	Alan Rindels	INV 852: Subsurface Drainage Manual for Pavements in Minnesota					56%	6	
\$71,050	\$10,493	LRRB	2006-097P	Mn/DOT Office of Materials	Roger Olson	Tim Stahl	Shirlee Sherkow	INV 861: Best Management Practices for Pavement Preservation of Hot Mix Asphalt.					25%		
\$70,500	\$60,561	LRRB	2006-096P	Mn/DOT Office of Materials	John Siekmeier	Larry Berkland	Shirlee Sherkow	INV 860: Compaction Specifications for Unbound Materials					50%		
\$70,007	\$0	LRRB	2006-107C, Task #11	SRF Consulting Group, Inc.	Michael Marti	Rich Sanders	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Pavement Management Systems					50%)	
\$70,000	\$38,500	LRRB	2006-060R	University of Minnesota	Henry Liu	Eric Drager	Shirlee Sherkow	INV 862: Real Time Arterial Performance				57	7%		
\$63,500	\$0	LRRB/ SRP/SP&R	2007-003R	University of Minnesota	Randal Barnes	Thomas Burnham	Shirlee Sherkow	INV 872: Mn/Road Data Mining, Evaluation and Qualification Phase 1						20%	
\$56,200	\$13,600	LRRB	2006-003P	Mn/DOT Office of Materials	Shongtao Dai	Brian Noetzelman	Dan Warzala	INV 840-1: Performance of PG 52-34 0il on Local Roads							33%

Total Cost	Amount Paid	Funding Source	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title		2006	2007	2008	2009	2010	2011
\$55,000	\$7,975	LRRB	2007-006R	University of Minnesota	John Gulliver	Rhonda Rae	Shirlee Sherkow	INV 875: Estimating the Size Distribution of Suspended Sediments in Minnesota Stormwater- Phase I: The Methodology							33%
\$54,495	\$0	LRRB	2006-107C, Task #13	SRF Consulting Group, Inc.	Michael Marti	Gary Danielson	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Guardrail and End Treatment Synthesis					10%	, D	
\$53,569	\$0	LRRB	2007-007P	Mn/DOT Office of Materials	Roger Olson	Doug Schwartz	Shirlee Sherkow	INV 876: Best Preventative Maintenance Treatments for Recreational Trails						25%	
\$52,980	\$7,947	LRRB	2006-015R	University of Minnesota - Duluth	Brian Brashaw	Chris Morris	Debra Fick	INV 853: Development of Flexural Vibration Inspection Equipment, Techniques to Assess Structural Health of Rural Bridge Systems II				-		0%	
\$50,663	\$0	LRRB	2007-001R	University of Minnesota	John Nieber	Alan Forsberg, Susan Miller	Alan Rindels	INV 870: Cost Analysis of Alternative Culvert Installation Practices in Minnesota						33%	
\$50,000	\$0	LRRB	2007-022P	Mn/DOT Office of Materials	Bernard Izevbekhai	Mark Maloney	Bruce Holdhusen	INV 879: Pervious Concrete Pavement in Mn/ROAD Low Volume Road							29%
\$50,000	\$0	LRRB/SRP	2008-051C	University of Minnesota	Gina Baas	Sue Lodahl	Sandy McCully	RSS Report Publication Services, 2009				-		50%	
\$46,035	\$45,766	LRRB	2005-034C	SRF Consulting Group, Inc.	Michael Marti	Julie Skallman	Sandy McCully	INV 999: LRRB Outreach/Communication Activities					839	%	
\$45,400	\$0	LRRB	2006-042R	University of Minnesota	Craig Shankwitz	Glen Ellis	Shirlee Sherkow	INV 845: Analysis of Highway Design and Geometric Effects on Crashes - Part II						20%	
\$45,000	\$15,000	LRRB	2007-041R	St. Louis County	Diwakar Gupta	Marcus Hall	Alan Rindels	INV 880: Snow Plow Optimization						3	3%
\$40,000	\$16,000	LRRB	2005-005P	Mn/DOT Office of Materials	Shongtao Dai	Michael Sheehan	Alan Rindels	INV 825: Performance Monitoring of Olmsted CR 117/104 and Aggregate Base Material Update							29%
\$31,997	\$0	LRRB	2006-107C, Task #12	SRF Consulting Group, Inc.	Michael Marti	Mark Maloney	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Stormwater BMP Maintenance					75%	ò	
\$31,040	\$17,313	LRRB	2006-006R	Minnesota State University, Mankato	James Wilde	John Brunkhorst	Clark Moe	INV 843-1: Predicting the Occurrence of Bumps in Overlays						50%	6
\$30,789	\$5,770	LRRB	2005-006P	Mn/DOT Office of Materials	Eddie Johnson	John Brunkhorst, David Linell	Clark Moe	INV 826: Appropriate Use of RAP					40%		
\$30,000	\$19,000	LRRB	2001-019P	Mn/DOT Office of Materials	Timothy Clyne	Lou Tasa	Dan Warzala	INV 768: Geosynthetics in Roadway Design							70%
\$25,564	\$21,730	LRRB	2006-107C, Task #2	SRF Consulting Group, Inc.	Michael Marti	Tom Behm	Clark Moe	INV 645: RIC Implementation of Research Findings (2007-2008) - Innovative Contracting Methods for Local Agencies					85%	ò	
\$20,000	\$7,000	LRRB	2007-004P	Mn/DOT Office of Materials	Roger Olson	Mark Maloney	Sandy McCully	INV 873: Use of Foamed Asphalt Base Reclamation on Local Roads					71%	Ď	
\$18,950	\$7,250	LRRB	2007-092C	MIS Sciences Corp	Jeff Willis	Sue Lodahl	Jake Akervik	Research Services and Local Road Research Board Web Site Hosting and Maintenance 2008 - 2009						429	6
\$17,910	\$9,945	LRRB/SRP	2007-018C	Darlene Gorrill	Darlene Gorrill	Sue Lodahl	Sandy McCully	INV 881: LRRB Annual Program/Technical Research Synthesis Reports					50%)	
\$7,938	\$7,938	LRRB	2007-066C	Athey Creek Consultants, LLC	Dean Deeter	Sue Lodahl	Nelson Cruz	INV 884: Redesign of Local Road Research Board (LRRB) Website			L	100%	ό		

Completed LRRB Research Reports and Implementation Products, January through October 2008

A mark in the "TS?" column indicates that a Technical Summary for this project can be found at http://www.research.dot.state.mn.us/.

Report Number	Project Title	Cost	Funding Source	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
2008-16	INV 817: Determination of Optimum Time for the Application of Surface Treatments to Asphalt Concrete Pavements - Phase II	\$226,000	LRRB/SRP	University of Minnesota, Mn/DOT Office of Materials	Mihai Marasteanu, Timothy Clyne, Heinz Stefan	Roger Olson	Dan Warzala	
2008-08	Development of Improved Test Rolling Methods for Roadway Embankment Construction	\$110,000	LRRB	University of Minnesota	Andrew Drescher, Joseph Labuz, Bojan Guzina	Tim Andersen	Clark Moe	Х
2008-42	INV 849: Study of Environmental Effects of De-lcing Salt on Water Quality in the Twin Cities Metropolitan Area, Minnesota	\$108,355	LRRB	University of Minnesota	Heinz Stefan, Omid Mohseni	Wayne Sand- berg	Becky Lein	Х
2008-06	INV 808: Pavement Rehabilitation Selection	\$102,000	LRRB	University of Minnesota, Mn/DOT Office of Materials	Joseph Labuz, Shongtao Dai	Brad C. Wentz	Dan Warzala	Х
2008-35	INV 833: Design Tool for Controlling Runoff and Sediment from Highway Construction	\$89,000	LRRB/SRP	University of Minnesota	Bruce Wilson	Brett Troyer	Dan Warzala	Х
2008-23	INV 857: Effects of Seasonal Changes on Ride Quality at MnROAD	\$79,493	LRRB/SRP	University of Minnesota	Lev Khazanovich	Ben Worel	Cory Johnson	Х
2008-25	Warrants for Right-Turn Lanes/Treatments on Two-Lane Roads	\$71,000	LRRB/SRP	North Dakota State University	Amiy Varma	Brian Gage	Nelson Cruz	Х
2008RIC03	Rural Road Safety Solutions Workshop Materials	\$63,871	LRRB	SRF Consulting Group, Inc.	Mike Marti	Rick West	Sandy McCully	Х
2008-54	INV 822: Crack Sealing and Filling Performance	\$62,802	LRRB	Mn/DOT Office of Materials	Eddie Johnson	Tom Struve	Shirlee Sherkow	
2008-28	INV 836: Design Procedure for Bituminous Stabilized Road Surfaces for Low Volume Roads	\$60,080	LRRB	Minnesota State University, Mankato	James Wilde	Roger Olson, Al Forsberg	Debra Fick	Х
MnPAVE08	INV 828: Local Road Material Properties and Calibration of MnPAVE	\$56,000	LRRB	Mn/DOT Office of Materials	Bruce Chadbourn	Jerry Geib	Dan Warzala	
2008-20	Best Practices Handbook for Roadside Vegetation Management	LRRB	\$52,500	Minnesota State University, Mankato	John Krenz	Paul Walvatne, John McDonald	Debra Fick	Х
2008-50	INV 841: Long Term Maintenance Effects on HMA Pavements Caused by Rumble Strips and Available Preventive Treatment Methods	\$43,257	LRRB	Mn/DOT Office of Materials	Roger Olson	Dennis Luebbe	Dan Warzala	
2008-24	INV 839: Toolbox to Evaluate the Impacts of Roundabouts on a Corridor or Roadway Network	\$39,444	LRRB	Iowa State University	Shauna Hallmark	Paul Stine	Clark Moe	Х
2008-32	INV 823: The Road to a Thoughtful Street Tree Master Plan	\$31,450	LRRB	University of Minnesota	Gary Johnson	Daniel Gullick- son	Debra Fick	
2008-02	INV 838: Evaluation of Paving Fabrics for Isolation of Bituminous Cracking	\$30,000	LRRB	Red Lake County	Courtney Kleven	Roger Olson, Lou Tasa	Alan Rindels	Х
2008-03	INV 827: Investigation of Winter Pavement Tenting	\$25,126	LRRB	Mn/DOT Office of Materials	Eddie Johnson	Tom Struve, Gary Brugge- man	Dan Warzala	Х
2008RIC06	Resource for Implementing a Street Sweeping Best Practice	\$21,493	LRRB	SRF Consulting Group, Inc.	Mike Marti, Joel Schilling	Tom Colbert	Sandy McCully	Х
2008RIC04	Training Module for Pavement Rehabilitation Selection	\$19,422	LRRB	SRF Consulting Group, Inc.	Mike Marti	Michael Sheehan	Clark Moe	Х
2008RIC08	Bridge Management Tool Phase I	\$19,400	LRRB	Bonestroo, inc.	Matt Shands	Petra DeWall, Tom Behm	Clark Moe	Х
TRS0801	INV: 881: Transportation Research Synthesis - Traffic Calming for High-Speed Rural Roadways	\$5,175	LRRB/SRP	Darlene Gorrill	Darlene Gorrill	Sue Lodahl	Sandy McCully	

The LRRB approves and funds the best innovative research that responds to ideas submitted by local transportation practitioners. Investigators from Mn/DOT, regional universities and consulting firms then conduct the selected research. The LRRB monitors the progress of this research, and Mn/DOT provides contract administration services, technical assistance and other administrative support.

MAKING A DIFFERENCE

The LRRB has helped local communities offer rural safety workshops, update crash analysis software, explore the environmental benefits of porous pavements, and evaluate the performance of storm water treatment technology.

GRASSROOTS INVOLVEMENT

The transportation practitioners who are responsible for county highways and city streets best understand the problems and challenges in providing safe, efficient roadways. The LRRB enables them to participate in setting the research agenda.





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Research Highlights

Recent LRRB-sponsored research includes many successful projects designed to help improve the quality of Minnesota's transportation systems.

In 2006, we partnered with Iowa State University's Center for Transportation Research and Education to develop a powerful and easyto-use Crash Mapping and Analysis Tool (for more information, see http://www.lrrb.org/pdf/2007RIC09TS.pdf) that engineers can use to identify problematic road locations and traffic control needs, assess how local construction and maintenance affect safety, and generate crash statistics for use in funding requests. LRRB also recently supported an effort to update the State Aid Concrete Pavement Rehabilitation Best Practices Manual (for more information, see http://www.lrrb.org/PDF/200631TS.pdf), which provides specifications for repair of city and county concrete pavements in Minnesota.

Currently, we are supporting a pavement preservation project investigating methods to extend the service life of pavement to as much as 60 years. (For more information, see http://www.lrrb.org/lrrbprojects.aspx?year=1&id=23.)



Partial-depth repair, a pavement rehabilitation procedure used when deterioration does not extend to the full depth of the pavement, is one of the procedures covered by the new State Aid Concrete Best Practices Manual, recently produced by the LRRB. This concise, definitive handbook provides guidance for city and county engineers to select the most costeffective ways to repair their roads, sidewalks, medians, curbs/ gutters, and more.