



2009 Annual Report



Minnesota
Department of
Transportation

RESEARCH SERVICES

Office of
Policy Analysis,
Research &
Innovation



Your Destination... Our Priority



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: www.dot.state.mn.us

Mn/DOT Research Services Section: www.dot.state.mn.us/research

Mn/DOT Library: www.dot.state.mn.us/library

Minnesota Local Road Research Board: www.lrrb.org

Minnesota Department of Transportation

RESEARCH SERVICES

2009 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 their ongoing efforts toward 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 *Minnesota Department of Transportation Research Services 2009 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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Included at the End of the Report:

2009 Research Services At-A-Glance

2009 LRRB At-A-Glance

2009 SP&R At-A-Glance

LIST OF 2009 TECHNICAL SUMMARIES

This report contains Technical Summaries for most research and implementation reports published from January through November 2009.

These are organized by Strategic Research Area (listed on page 28). The listing below gives the Mn/DOT report number and the title of the report summarized.

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Director's Message



Linda Taylor,
Director, Mn/DOT Research
Services Section

We are pleased to present the *Minnesota Department of Transportation Research Services 2009 Annual Report*.

This report describes our products, projects and services, and highlights many of our accomplishments during the past year. The report also fulfills a federal requirement to report on the research program's finances, progress and results. More importantly, the information in these pages constitutes another step toward greater accountability and transparency to Commissioner Thomas K. Sorel, Mn/DOT's leaders and district offices, the Local Road Research Board and Minnesota's taxpayers. We hope this report promotes sound research investments and the continued improvement of the state's transportation system.

Our innovation and technology transfer activities support Mn/DOT and local governments in the stewardship of the funds they receive and advance Mn/DOT's Strategic Directions. The innovations we deliver help maintain Minnesota's transportation infrastructure, including our highway and bridge system, local roads and highway alternatives such as transit. Our programs are critical to increasing the safety of Minnesota travelers as well as their confidence in Mn/DOT.

Our annual report continues to evolve from year to year as our program evolves. Key elements of this publication include the following:

- Mn/DOT's research program and library services are presented, including a staff listing, an overview of our goals and activities, and a description of our partnerships and programs.
- The bulk of the *Annual Report* is composed of Technical Summaries, which are two-page summaries of most of the research projects that were completed in 2009.
- Reporting on the Transportation Pooled Fund/State Planning & Research program has been expanded this year with highlights of projects led by Mn/DOT and other high-profile, multi-state projects that we contribute to.
- The *Research At-A-Glance* documents, located at the back of the *Annual Report*, provide a snapshot of completed and ongoing research projects carried out for Mn/DOT, the LRRB and Transportation Pooled Fund studies funded through the SP&R program.

Strategic Vision, Strategic Research

2009 marked a time of continued transition for Mn/DOT's Research Services Section with its ongoing incorporation into the new Office of Policy Analysis, Research & Innovation, and its alignment with Mn/DOT's Strategic Vision and Directions. 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.

2010 brings with it many challenges both at a local and national level as agencies face budget shortfalls, staff reductions and increased demands for limited resources, which in turn lead to increased scrutiny of programs.



As the new director of Research Services since May 2009, my goals are to:

- Ensure a sound and balanced research program that meets department needs and maintains Minnesota as a global leader.
- Promote transparency by marketing our services and products, soliciting input from stakeholders, and expanding and leveraging partnerships.
- Update the library into a state-of-the-art facility using emerging technologies to facilitate library knowledge networking systems and effective use of Web 2.0 tools.
- Raise awareness within the Department of the services offered by the Research Services Section and of our program responsibilities.
- Increase our focus on technology transfer and communications.

2009 Program Highlights

- **Peer Exchange Management Update:** Mn/DOT hosted a value of research workshop and peer exchange November 2-4, 2009. The results from the peer exchange are being used to develop a Research Communication Plan, refine the program and explore opportunities to collaborate with partners to reach stakeholders more effectively.
- **Mn/DOT Library** completed its business plan, conducted user focus groups, hired additional staff, purchased electronic document readers and updated its collections. In 2010, we will upgrade the library space to make it more user friendly.
- **Outreach activities** included hosting webinars on high-profile research projects through the Research Innovation Presentation Series, producing Technical Summaries of all research projects, expanding the use of Research Synthesis Reports, and conducting usability studies of the LRRB and Research Services Section Web sites.
- The **Next Generation Automated Research Tracking System**, or **ARTS-NG**, was implemented to better monitor and track end-user products, roadmaps and contract project relations. This will be further enhanced in 2010 to support research and budgetary needs.
- Our **Research Program Business Flow** was documented to improve program management processes.

Please feel free to contact me or any of the Research Services Section staff for additional information on our products or projects. I would encourage everyone to take advantage of our professional library and research staff to help identify research needs and determine the state of practice. 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.

LINDA TAYLOR
Director, Mn/DOT Research Services Section
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“There’s no doubt we need strong partnerships and strong research to create 21st century solutions.”

—Thomas K. Sorel,
Mn/DOT Commissioner



“Sound research leads to safer streets and lower costs.”

—Bernie Arseneau,
Director, Mn/DOT
Division of Policy, Safety
& Strategic Initiatives



“New initiatives make it easier for us to ensure that research dollars are being directed appropriately toward Mn/DOT’s Strategic Research Areas.”

—Nick Thompson,
Director, Mn/DOT
Office of Policy Analysis,
Research & Innovation

Mn/DOT Research and Library Services



Most Research Services staff members are headquartered at the Mn/DOT Transportation Building in St. Paul.

Our Mission

Mn/DOT Research Services supports measurable improvements in Minnesota's transportation system by meeting the innovation and information needs of transportation practitioners and the transportation community.

Research and Library Services provides administrative support, financial management and informational services to:

- The Local Road Research Board
- Minnesota's State Research Program
- The FHWA State Planning and Research program in Minnesota.

With the help of our university and consultant partners, we pursue practical innovations that will be 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, exceeding customer expectations and saving taxpayer money.

We fund innovation needs throughout the year and invite new

ideas from Mn/DOT staff and others; see the "Submit an Idea" link on our Web site (www.dot.state.mn.us/research). We solicit proposals for 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.

Research Services Management

Mn/DOT Research Services, under Linda Taylor's leadership, is responsible for the day-to-day operations of the research programs we manage and the Mn/DOT library. As director of Research Services, Taylor is the liaison to upper management and to other Mn/DOT divisions, offices and sections. She is also responsible for transparency and efficiency in research operations and communications, providing leadership in shaping communication and reporting strategies, and organizing Research Services staff and their priorities to continually improve the stewardship of state, federal and local transportation dollars. She is Mn/DOT's representative to the Transportation Research Board and to the Research Advisory Committee of the American Association of State Highway and Transportation Officials and serves as secretary on the LRRB board. She is also a member of many other steering and advisory committees.

Mn/DOT's leadership has identified **eight strategic areas for research**, as described in "Mn/DOT's State Research Program." The role of Research Services management is to provide ongoing input about the status of these topics and to ensure that overall Mn/DOT strategy guides Research Services activities.

This involves such measures as directing the administration and development of the innovation roadmaps that are used to manage the research priorities of various Mn/DOT offices.

Research Identification and Project Management

Mn/DOT Research Services staff members help identify innovation needs throughout the department using research innovation roadmaps, research needs statements and other tools to determine what tangible problems can best be addressed through formal research investigation. Research Services helps to define an end-user product that will satisfy a given need, and the research and implementation contracts necessary to develop and deploy this product.

Administrative liaisons ensure that contracts are followed and that deliverables are submitted and approved. They work with technical liaisons—subject matter experts from Mn/DOT or Minnesota counties—to manage and evaluate projects throughout their life cycles, from contracting through implementation and technology transfer.

Some administrative liaisons also function as roadmap managers to coordinate the projects designed to develop a given end-user product and all the related products that guide priorities and planning within a given strategic research area.

Staff members also coordinate efforts with state and national cooperative research programs including the Transportation Pooled Fund Program, the chief target of Federal Highway Administration State Planning and Research funds.

Library and Information Services

The Mn/DOT Transportation Library, under the 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 help Research Services to identify existing research in a given area to ensure that



all projects begin with a firm foundation and to avoid duplication of efforts. They help patrons navigate electronic resources and answer ad hoc information queries that help engineers and managers save time and money. 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 the Local Technical Assistance Program, 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 also provides access and shared information resources on local, state, regional, national and international bases by participating in 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.

Research Implementation, Outreach and Technology Transfer

The diagram on page 10 illustrates the cycle of innovation activities from research to deployment.

Mn/DOT's research roadmap managers (from left): Bruce Holdhusen, Alan Rindels and Clark Moe.

During the project and roadmap planning processes, staff members determine measures required for successful implementation and ensure that these are built into research contracts. When a research contract ends, Research Services evaluates the results to determine the most appropriate actions to take given the progress of the research. Steps may include additional work to further develop usable end-user products such as specifications or manuals, demonstrations, training and technology transfer activities to inform potential users of research findings and enable them to make the best use of developed resources. Administrative liaisons for implementation contracts identify the impacts of research investments and measure the performance of individual projects and 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 Research Innovation Presentation Series, program reports and the LRRB's

bimonthly newsletter; maintain the Research Services and LRRB Web sites; and, in conjunction with LTAP, facilitate training efforts to help maximize Mn/DOT's research investments.

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

Financial Services

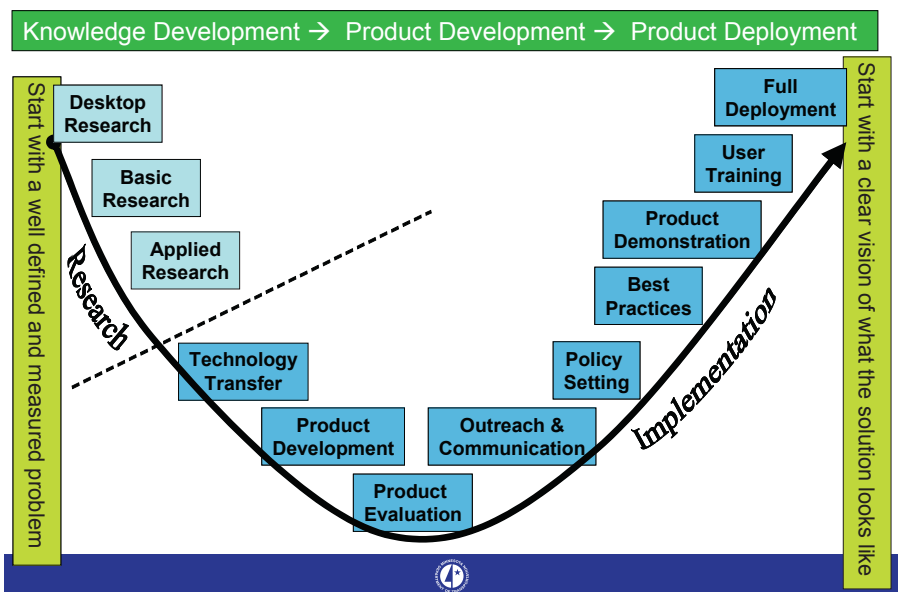
Research Services Financial Services staff members coordinate research contracts and funding processes, including contract creation; budget management; and local, state and national research funding coordination. These individuals also handle Research Services-related purchasing, including travel arrangements for meetings and conferences.

They serve as experts on available funding sources for research and provide help to Mn/DOT and (through LRRB) local practitioners and managers to determine the most appropriate sources of funding for research projects.

What is an Innovation Roadmap?

A plan of related projects to solve the problem and deploy results

This diagram illustrates the cycle of innovation activities from research to deployment. Research is only the first step in ensuring deployment of a usable end-user product with a measurable benefit to transportation in Minnesota.



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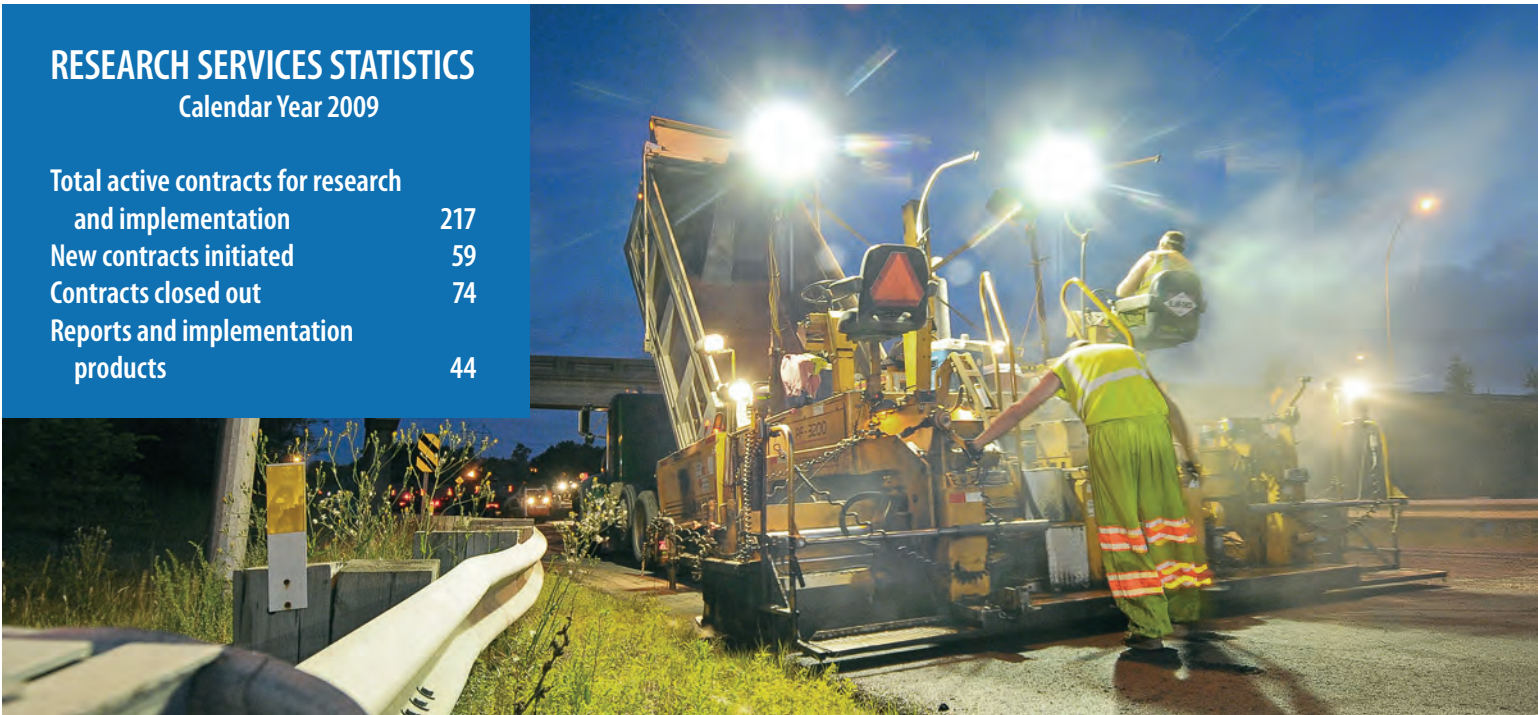
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Research Services 2009 Vision, Accomplishments and Initiatives

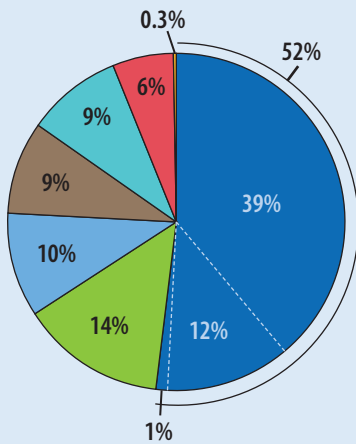
RESEARCH SERVICES STATISTICS

Calendar Year 2009

Total active contracts for research and implementation	217
New contracts initiated	59
Contracts closed out	74
Reports and implementation products	44



FY 2009 Funding Distribution by Mn/DOT Strategic Research Area



Total: \$6,227,990*

*Includes only projects with an assigned end-user product

Infrastructure preservation
52% \$3,234,458
Roads: 39% \$2,444,984
Cost-effective preservation, optimization of recycled materials
Bridges: 12% \$735,905
Best management practices, addressing cumulative overloading
Other: 1% \$53,569
Trail maintenance

Innovative project delivery
14% \$853,531
Positive culture change, civil rights emphasis, remote sensing, accelerated construction and project development, data mining

Congestion management
10% \$626,250
Cost/benefit focus, A+B contracting, design-build, demand management, optimizing cost-effectiveness

Traffic safety
9% \$562,466
Low-cost improvements, rural roads, Toward Zero Deaths, Americans with Disabilities Act Title II

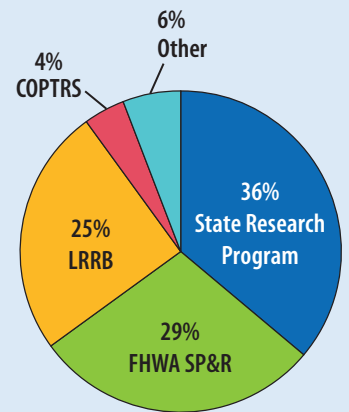
Green roads
9% \$531,487
Environmental stewardship, global warming, energy efficiency, roadside management, clean water

Multi-modal infrastructure
6% \$397,511
Freight, truck size and weight, commerce and transportation industry balance, effects of anti-icing chemicals

Organization transformation
0.3% \$22,287
Collaboration, changing demographics, customer service focus, cost-effective program delivery

Addressed through progress in other focus areas with communication of results:
Responding to customers and stakeholders
Building public confidence, transparency, Hear Every Voice, ADA, gas price impacts, legislative decision making, innovative contracting and financing

FY 2009 Funds Available



State Research Program:	\$3,400,000
FHWA State Planning and Research (Part II):	\$2,742,215
Local Road Research Board:	\$2,391,365
Cooperative Program for Transportation Research and Studies:	\$375,000
Other*:	\$549,000
Total:	\$9,457,580

*Includes contributions from other Mn/DOT offices (Maintenance, Traffic, Materials, Investment Management and Policy Analysis, Research & Innovation) and districts along with the Twin Cities Metropolitan Council.

As mentioned in the director’s message, 2009 was a year of reorganization. This section includes descriptions of some of our newer programs and initiatives.

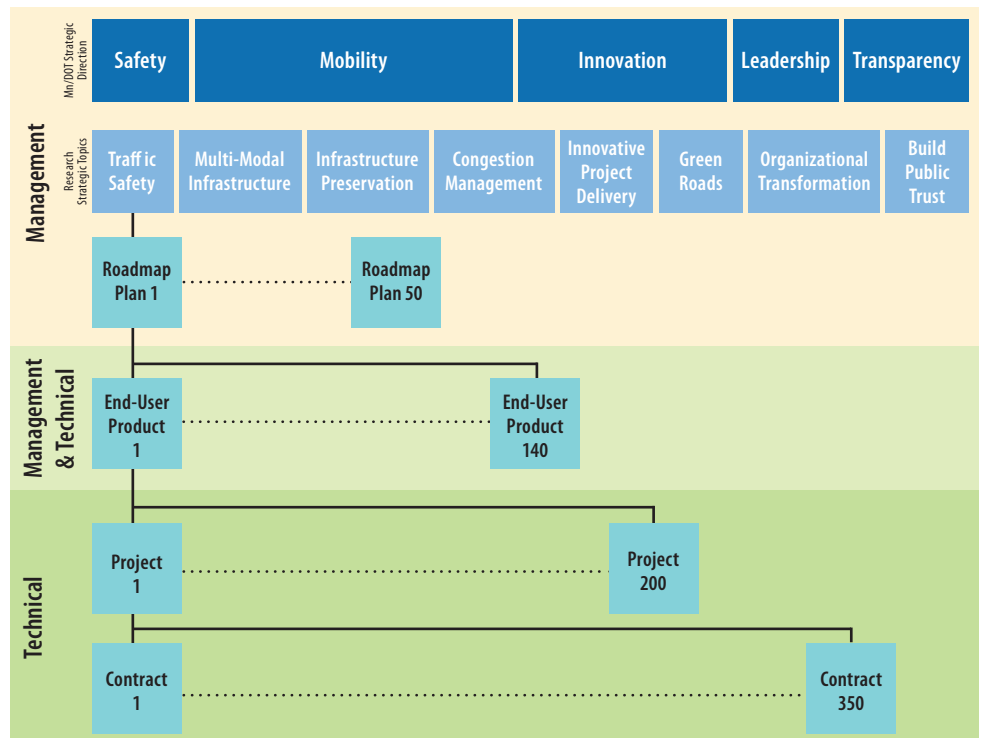
A New Conception of Research: Organization, Oversight and Accountability

Over the last two years, Research Services has redefined the way it approaches research. Previously, research proposals were evaluated more or less individually; when a project was completed, additional funds might be requested for follow-up research or for project implementation.

Now, we look at projects hierarchically, as illustrated in the diagram:

- **Mn/DOT’s strategic directions** (described in more detail on page 14) govern the entire department’s activities.
- **Eight research focus areas** were developed to translate these strategic directions into defined research directives.
- **Approximately 60 research roadmaps** have been designed to organize efforts within a given research focus area. Research Services works with Mn/DOT offices to define and prioritize specific goals within a given research area, and these define the roadmaps for that area.
- **Over 115 end-user products** have been defined within particular roadmaps. These products include changes in specifications, recommendations for revising legislation, new technologies, best practices manuals and training curricula.

Research Hierarchy: From Planning to Implementation



- **Research projects** must each have a defined end-user product that advances research along a defined roadmap. Individual projects may be initiated to develop different aspects of an end-user product (for example, to test the different technologies involved in a new set of recommended practices), but researchers can clearly determine a project’s success by its ability to advance product development.
- **Research contracts** are assigned to projects to manage and evaluate work by specific contractors. A project may have multiple contracts corresponding to different contractors or project phases, such as researching an issue, creating manuals and training materials based on research results, and developing publicity or taking legal steps to implement the results.

Mn/DOT's Strategic Directions



Mn/DOT's leaders have defined the following strategic directions to elaborate the department's core values. (More information is available at www.dot.state.mn.us/strategicvision/vision.html.)

Safety—Promote and maintain a safe, reliable and modern transportation system

- Reduce transportation-related fatalities and injuries through the use of new and improved technology and safety measures
- Monitor the condition of existing infrastructure in order to maintain a reliable and efficient transportation system

Mobility—Improve access and enhance the movement of people and freight

- Ease congestion, reduce commute times and improve the quality of life and economic well-being of all Minnesotans
- Promote mass transit and use all modes for improving mobility and accessibility in the Metro and in Greater Minnesota

- Maximize operational efficiency of Interregional Corridors

Innovation—Promote a culture of innovation in the organization

- Foster innovation and collaborative partnerships within the transportation community in delivering 21st century transportation solutions
- Develop ground-breaking, multi-modal transportation practices that will accommodate the diverse needs of all individuals and communities
- Encourage research and build capacity to develop, implement and sustain solutions that balance preservation needs and address congestion issues

Leadership—Become the transportation leader and employer of choice for Minnesota's diverse population

- Mobilize in-house talent, public input and external partnerships to deliver value to the public
- Value service, excellence and diversity to be an employer of choice
- Provide development and advancement opportunities for all employees
- Empower all employees to be leaders and ambassadors for Mn/DOT

Transparency—Build public trust in Mn/DOT

- Develop a simple, yet comprehensive tool for measuring performance across functions that is efficient, accurate, cost-effective and will show accountability to the public
- Build relationships within local communities and encourage public involvement in developing transportation solutions
- Effectively tie the strategic vision to Mn/DOT's long-range transportation plan, strategic plan and investment objectives, serving as an ethical compass for decision making at all levels

Transportation Research Innovation Group (TRIG)

Research Services created TRIG to provide guidance and direction for Mn/DOT's research. This group of Mn/DOT upper-level managers from the Mn/DOT districts and specialty offices reviews research requests for proposals, innovation and implementation proposals, and National Cooperative Highway Research Program project nominations and panel recommendations.

Serving Cities and Counties

Research Services applies these newly developed research methods and tools to all the research we manage, including Local Road Research Board projects. This helps us to organize our project management efforts, evaluate project successes, and facilitate communication and collaboration between Mn/DOT and local governments to ensure that research is not duplicated and that each organization can take maximum advantage of research funded by the other.

Streamlining Processes

Along with this new approach to research, we developed a **Research Program Business Flow** to better define and document the roles, duties and points of communication within Research Services. This system includes a resolution tree, a process to resolve conflicts in research schedules, budgets and the performance of various participants in our research process. We hold regular research project review meetings to identify problems early in the process.

Business flow information was used to update and optimize our research tracking database, **ARTS: A Next-Generation Automated Research Tracking System**. This system records the deliverables, task statuses and budgetary items that Mn/DOT administrative liaisons need to track projects. Our new version of this tool, **ARTS 2.0**, offers more layers of record-keeping corresponding to the elements of our research hierarchy, and offers flexible reporting and access features to ensure that information is documented and shared.

One key tool we created to streamline financial dealings was the **Transportation Research Assistance Program**. TRAP provides a list of consultants that have been pre-approved to support our research program, allowing for quick selection of experts qualified through TRAP Requests for Proposals on projects with limited budgets. Research categories include technical writing and editing, outreach and education, event coordination, data information analysis and program/project coordination.

Outreach and Technology Transfer

Delivering news of innovations to our customers is the cornerstone of our program. This is essential for ensuring that Minnesota is getting the most out of our research investments.

The flagship product of our technology transfer efforts is the **Technical Summary**. This year, we produced two-page summaries of most research reports published in 2009; these have been reprinted at the end of this publication. Our **2008 Annual Report** was well-

received, and we created a pilot **Management Update** to increase transparency through more frequent reporting of core research statistics and new developments throughout the year.



The **Research & Innovation Presentation Series** was initiated to inform Mn/DOT staff and stakeholders about leading-edge or high-visibility research and department initiatives. This series is planned to continue at quarterly intervals and offers teleconference/webinar functionality to enable wide participation. Recent topics included the Office of Policy Analysis, Research & Innovation risk management initiative (June), roadside vegetation management (October) and changeable message signs (January 2010).

A recent RIPS presentation discussed current research efforts in roadside vegetation management.

Usability testing on the Research Services and LRRB Web sites was performed at the University of Minnesota's state-of-the-art Usability Lab. The students' analyses will be used to improve these Web sites beginning in 2010. Focus areas for the evaluation included search functionality, site links and navigation, aesthetics and integration of Web 2.0 technology.

We conducted a **University Research Project Selection Survey** to gather feedback from Mn/DOT management and other research stakeholders. This survey included questions about idea gathering and scoping, proposal review and ranking, TRIG, research roadmaps and end-user products, and communication. The information gathered was used to help understand internal stakeholders' concerns and improve our processes. We intend to incorporate the survey in our annual program review and improvement process.

In September, we helped administer the **Mn/DOT E-Magination Jam** over the Internet to generate and prioritize ideas for fulfilling our organizational goals. This project produced more than 500 innovative ideas, which are currently being reviewed by the Office of Policy Analysis, Research & Innovation and upper management for selection and implementation. The same software used for this effort (uservice.com) was

subsequently used to create a **University Research Proposal Voting and Discussion** Web site to enable collaboration among Research Services and other research stakeholders.

Members of Research Services, the Library and the Office of Traffic, Safety and Technology co-sponsored a booth at the 2009 **Toward Zero Deaths Conference** October 28-29, 2009. We were able to share the results of many recent Mn/DOT and LRRB research projects and initiatives. More information about this inter-agency effort is available at www.MinnesotaTZD.org.

Research Services hosted a **peer exchange on Communicating the Value of Transportation Research** November 2-4, 2009, in Shoreview, Minn. Representatives (pictured below left) from eight state DOTs, two Minnesota universities and FHWA—Minnesota joined representatives from Mn/DOT to learn about effective strategies for communicating the value of transportation research and to share best practices. A number of Mn/DOT program areas participated, including Traffic; Materials; State Aid; Research Services; Maintenance; Market Research; Communications; the Office of Policy Analysis, Research & Innovation; and the LRRB. For more information, see www.newsline.dot.state.mn.us/archive/09/nov/24.html#Z6.

More information about all of these efforts, including links to Technical Summaries and RIPS presentation videos, is available at our Web site: www.dot.state.mn.us/research.



Representatives from eight state DOTs, two universities and FHWA—Minnesota joined Research Services staff at the Communicating the Value of Transportation Research peer exchange.



The Toward Zero Deaths Conference gave us the opportunity to share Mn/DOT and LRRB research into policies and designs that will help keep Minnesota's roadways safe.



The research we enable covers a wide range of topics: Mn/DOT worked with the University of Minnesota's Center for Transportation Studies to produce Joel Katz's *From Footpaths to Freeways* (Report HE365M6), a book covering the history of transportation in Minnesota. This work provides historical context for the political and practical constraints involved in the criteria for design and construction of the interstate highway system.

Mn/DOT Library 2009 Accomplishments and Initiatives



The Library is well-known for its historic, fully catalogued and easily accessible collection of transportation planning and civil engineering materials.

developments. “These materials have helped Mn/DOT quickly learn the pros and cons of this mode of travel and should greatly help us develop a comprehensive direction in this area,” Thakur said.

New Services and Collections

In 2009 the Library continued its tradition of excellent service while expanding its resources and meeting several goals in its 2008 business plan. The Library:

- Added 11 periodical titles, including *The Economist* and the *Journal of Transportation Safety & Security*, while dramatically reducing the cost of its periodical subscriptions by changing vendors.
- Established a reading area called the Commissioner’s Reading Corner and stocked it with books on leadership techniques that staff members can use in their work. Purchased books include *Lincoln on Leadership: Executive Strategies in Tough Times*, by Donald T. Phillips, and *Letters from Leaders: Personal Advice for Tomorrow’s Leaders from the World’s Most Influential People*, by Henry O. Dormann.
- Secured funding to update its book collection in a variety of topics, including bridges, intelligent transportation systems and project management.
- Planning to install Wi-Fi so that customers can access the Internet with their own computers.

Reaching Customers

The Library also strives to make its services and resources accessible to the widest possible audience. Last year the Library added 100 new customers and conducted numerous outreach efforts to make Mn/DOT staff aware of its services. The Library:

- Sent letters introducing its services to 125 new employees, and regularly notified existing employees of periodicals that might be of interest.
- Distributed *New Library Materials*, its monthly newsletter, to more than 800 subscribers, and increased its distribution list by advertising in *Newsline*, the Mn/DOT employee newsletter.
- Conducted an open house for more than 200 attendees; the event included informational displays, new book highlights and the opportunity to get to know the Library’s information professionals.

For 53 years, Mn/DOT librarians have been helping engineers and other professionals save time by assisting them with research. With a combined 79 years of experience, the Library’s six staff members are experts at quickly finding information in electronic databases and through online searches.

These services have been critical to the work of such customers as Mukhtar Thakur, Mn/DOT director of Technical Support. Recently the Library staff conducted research about personal rapid transit for Thakur, providing key reports and presentations, strategic forecasts and ongoing e-mails about the latest

Planning Ahead: Library Business Plan, Phase II

As it meets existing goals, the Library continually plans ahead for improvements. From April to June, it conducted four focus groups with 32 internal and external customers to better understand their needs and develop the second phase of the Library business plan. Interviewees included Mn/DOT engineers, technical experts and nonengineers; and external customers such as city and county engineers, consultants and LRRB members.

Results of these focus groups led to several recommendations that served as the foundation of Phase II of the Library's business plan, including steps to:

- Investigate new technologies to meet the needs of customers and make the work of librarians more efficient.
- Develop a marketing and communications plan that identifies and assesses customer groups and media content with key messages targeted to these groups.
- Develop a library advisory group to engage management and other stakeholders in making and supporting key Library decisions.
- Redesign the physical space of the Library to better meet customer needs.

This proactive approach pays huge dividends for Mn/DOT personnel. If a resource is not immediately available, Library staff will make every effort to obtain it. Traffic, Safety & Technology engineer Ken Schroepfer needed a CD-ROM for a critical training program with Minnesota cities and townships, but the only one on hand was damaged. "Through the Library's efforts, a complete CD-ROM was found, and I will be able to teach city and township workers the proper way to install and maintain roadway signs," said Schroepfer. "This training program will help build relationships between Mn/DOT and the cities and townships within Minnesota."

Library Statistics

(Estimated for Calendar Year 2009)

Library materials circulated	16,897
New materials acquired	802
Questions answered	1,220
Literature searches	389
Interlibrary loans	876



Far from being simply caretakers of a physical collection, Mn/DOT librarians are information experts, skilled at quickly navigating ever-expanding electronic databases to find the right resources for a given problem.

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 each office to develop a project that will address 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 given below.

Mn/DOT Districts

- District 1: Duluth
- District 2: Bemidji
- District 3: Brainerd
- District 4: Detroit Lakes
- Metro District
- District 6: Rochester
- District 7: Mankato
- District 8: Willmar

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
- Human Resources
- Investment Management & Performance Measures
- Land Management
- Maintenance
- Materials
- Project Scope & Cost Management
- State Aid for Local Transportation
- Technical Support
- Traffic, Safety & Technology
- Transit
- Transportation Data & Analysis

Other Mn/DOT Offices' Research Programs

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 six miles of pavement sections with embedded electronic sensors. Researchers around the world use the MnROAD facilities and data. www.dot.state.mn.us/mnroad

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 and private sectors and with academia.

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 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 also supports laboratory research. The New Technology Research and Equipment Committee, or NTREC, approves funding for project proposals exceeding \$12,000 and reviews the success of conducted research.

www.dot.state.mn.us/maintenance/research/index.html

Mn/DOT External Academic Partnerships

University of Minnesota

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. Mn/DOT research is also performed on the Duluth campus. www1.umn.edu/twincities/index.php



Since its inception in 1987, CTS and Research Services have maintained a strong partnership.

Center for Transportation Studies (CTS)

Located on the Twin Cities campus, CTS 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. The mission of Mn/DOT's partnership with CTS 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.

www.cts.umn.edu

Humphrey Institute of Public Affairs

The Humphrey Institute of Public Affairs ranks among the top professional schools of public affairs at public universities in the country. Its expert researchers work with Mn/DOT and the LRRB on a variety of policy projects to improve Minnesota's multi-modal infrastructure and transportation planning practices.

www.hhh.umn.edu

Center for Excellence in Rural Safety (CERS)

CERS is a joint program between CTS and the Humphrey Institute that works with the LRRB to provide citizen-centered research, training and outreach to enhance rural safety and to meet the online and seminar training needs of rural transportation practitioners and policymakers. www.ruralsafety.umn.edu

Intelligent Transportation Systems Institute (ITS)

The ITS Institute is a federally funded University Transportation Center, conducting activities that further the mission of the U.S. DOT's UTC program: to advance U.S. technology and expertise in transportation through education, research and technology transfer activities. www.its.umn.edu

ITS programs and dedicated laboratories include:

- [HumanFIRST Program](#)
- [Intelligent Vehicles Laboratory](#)
- [Minnesota Traffic Observatory](#)
- [Northland Advanced Transportation Systems Research Laboratories](#)
- [Planning and Policy for ITS](#)

Minnesota State University, Mankato

Minnesota State University, Mankato recently created the Minnesota Center for Transportation Research and Implementation. This 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. www.mnsu.edu

Minnesota State Colleges and Universities— 37 Public Institutions

Additional Minnesota university partners work at other institutions in the MSCU system. www.mnscu.edu

Out-of-State 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

Operational Research Assistance Program (OPERA)

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

Minnesota Local Technical Assistance Program (LTAP)

The Minnesota LTAP is part of the 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. www.mnltap.umn.edu

The LRRB supports the local OPERA effort and Minnesota LTAP.

Transportation Engineering and Road Research Alliance (TERRA)

Funded through SP&R project TPF-5(215), TERRA was introduced 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.

www.terreroadalliance.org

American Association of State Highway and Transportation Officials Research Advisory Committee (AASHTO RAC)

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://research.transportation.org>

Federal Highway Administration (FHWA)

FHWA provides financial support for Mn/DOT research activities through the SP&R program. Efforts and organizations within FHWA work with Mn/DOT in other specific ways.

Turner-Fairbank Highway Research Center (TFHRC)

TFHRC is a federally owned and operated research facility in McLean, Va. It 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.

www.tfhrc.gov

FHWA Minnesota Division Research/Technology Transfer

The Minnesota Division is responsible for overseeing FHWA's SP&R Program and LTAP in our state.

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



FHWA Transportation Pooled Fund Program (TPF)

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. www.pooledfund.org

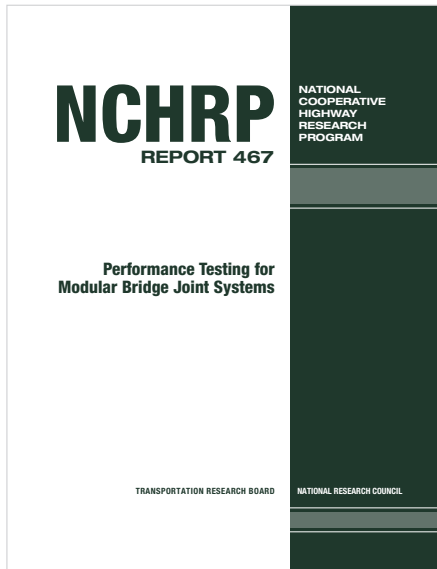
Mn/DOT Research Services leadership strategized with other state DOT research leaders at the July 2009 National RAC Meeting in Orlando, Fla.

Transportation Research Board (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 multi-modal.

TRB also administers a number of major research programs sponsored by other organizations, including NCHRP.

www.trb.org



NCHRP reports often serve as guidelines for Mn/DOT practices. *NCHRP Report 467*, published in 2002, introduced bridge design standards that all new bridges and replacements must follow.

National Cooperative Highway Research Program (NCHRP)

NCHRP is sponsored by the member departments (individual state DOTs) 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.

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



About LRRB

For more than 45 years, the LRRB has brought the latest developments in transportation research to the state's city and county engineers, sponsoring more than 200 projects in areas ranging from cold-in-place recycling with foamed asphalt to the use of pervious concrete for stormwater management.

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

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

For more information about the LRRB's projects and activities, go to www.lrrb.org and search for reports and Technical Summaries or initiate queries. 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 a guide to pavement management systems, a training module on selecting pavement rehabilitation techniques, a Project Memo Writer, the Geosynthetic Design Guide, the Minnesota Research Test Section Tracking database and the Mix Asphalt Design Tool.

LRRB-Sponsored Research

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.

This approach allows the LRRB to leverage the collective knowledge of the local transportation practitioners who best understand the problems and challenges involved in providing the public with safe and efficient roadways. The LRRB makes it easy for them to set and participate in the agenda for transportation research in Minnesota.

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

The LRRB sponsors 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**

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.



University of Minnesota researchers developed the SMART-SIGNAL system to cost-effectively collect and archive high-resolution traffic signal data and automatically generate real-time performance measures such as travel time, queue length and intersection delay. Engineers can use SMART-SIGNAL data, collected via detection units installed in signal cabinets like this one, to optimize timing schedules on each traffic signal to reduce congestion without additional road construction.

Research Highlights

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

The Systematic Monitoring of Arterial Road Traffic Signals, or SMART-SIGNAL, system (presented in [Report 2009-01](#)) was developed to collect and archive high-resolution traffic signal data and automatically generate real-time performance measures such as travel time, queue length and intersection delay. These performance measures were used to demonstrate the benefits of new signal timing plans implemented by Hennepin County. This project received the 2009 CTS Research Partnership Award and has spawned additional research. Studies are already under way to test a retooled prototype of SMART-SIGNAL and fine-tune its data collection equipment to prepare for the next generation of signal controller cabinets and to create a Web interface for end users.

Another key research area was the use of recycled materials in construction and reconstruction, which can save money and remove the need to landfill these materials. As the use of these materials increases, the LRRB is helping pavement engineers understand how well they perform in pavements, how and when they are best used, and what their environmental effect might be. Materials studied in reports completed in 2009 included recycled asphalt pavement (evaluated in LRRB reports [2009-05](#) and [2009-15](#)), foamed asphalt ([2009-09](#)), industrial fly ash ([2009-27](#)), tire shreds ([2009-02](#)) and other materials ([2009-32](#) covered several different options).

Implementation and Education

Over the last 15 years, the LRRB has sponsored more than 200 individual research projects on a variety of topics. We have also helped local communities offer pavement management, rural safety and snowplow sander calibration workshops; update their crash analysis software; explore the environmental benefits of porous pavements; and evaluate the performance of stormwater treatment technology.

Knowledge Building Priorities

In 2009 LRRB updated its Knowledge Building Priorities, which define long-term, complex transportation issues affecting local government agencies that could be addressed with research. Using input from members, city and county practitioners, Mn/DOT staff and University of Minnesota researchers, LRRB updates these priorities every four to five years to address changing transportation issues facing cities and counties. Priorities include roadway safety, use of recycled and alternative pavement materials, innovative contracting methods and the reduction of environmental impacts.

The LRRB also sponsored efforts to evaluate the effectiveness of pavement preventive maintenance techniques on recreational trails (2009-25) and roadway subsurface drainage practices (2009-08).

The RIC produced a number of very useful guides for local agencies including the Stormwater Maintenance Best Management Practices Resource Guide (2009RIC12), Innovative Contracting Methods (2009RIC02) and the educational toolbox Implementation of Pavement Management in Minnesota (2009RIC11).

A full list of LRRB-sponsored reports and implementation products completed in 2009 as well as a list of in-progress contracts can be found in the *LRRB At-A-Glance* insert accompanying this report. Technical Summaries for most projects completed this year can be found at the end of this document; please see the table of contents to locate individual summaries.



The LRRB-sponsored [Report 2009-25](#), *Preventive Maintenance for Recreational Trails*, describes how techniques designed for roadways such as chip sealing (pictured here) need to be modified for use on trails.

In *Best Practices for RAP Use Based on Field Performance (2009-15)*, researchers used dynamic modulus testing equipment on pavement samples from projects using different recycled asphalt pavement mixtures, testing their stiffness over a range of temperatures. While RAP is commonly used in pavements, this study was among the first to systematically evaluate its use in the pavement's wear course, or top layer. This puts Minnesota on the forefront of such usage, which has the potential to substantially reduce the cost of road construction.

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.

Strategic Areas for Research

In June 2007, Mn/DOT leaders met in a Strategic Visioning seminar to translate these strategic directions into eight research areas to guide State Research Program investment priorities through the coming years. Research Services then developed or augmented tools to make sure research efforts are focused on these priority areas. **Research roadmaps** lay out specific paths forward for achieving goals in each focus area. **Defined end-user products**—each of which is associated with a roadmap—clarify the desired outcomes for Mn/DOT from each project under consideration. **Detailed post-contract evaluations** assess the degree to which each project has followed its roadmap and advanced development and deployment of its end-user product.

1. Provide a multi-modal infrastructure

- Freight
- Truck size and weight
- Balancing commerce direction and 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

- Positive culture change: increased use of technology, quality, innovation across the organization
- Civil rights emphasis: e-bidding
- Remote sensing
- 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

- Toward 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: Americans with Disabilities Act 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

Research Highlights

A critical ongoing concern for Mn/DOT is **management and preservation of Minnesota's bridges**.

- A report on Crack and Concrete Bridge Deck Sealant Performance (**2009-13**) addressed a key bridge maintenance issue by testing the various products available for sealing the cracks in prestressed concrete bridges that, if left untreated, can lead to infiltration of corrosive substances that damage the steel reinforcement. This study laid the groundwork for a new implementation project that will make final recommendations regarding products and practices.
- Mn/DOT also pursued new information-gathering technologies and information management techniques for bridge preservation. In Bridge Health Monitoring and Inspections Systems—A Survey of Methods (**Report 2009-29**), researchers evaluated a range of technologies and methods available for remote monitoring of bridges and developed a database tool to aid bridge engineers in deciding which solutions are most appropriate for a given application.
- Mn/DOT implemented a fatigue detail classification scheme for its bridges (explained in Technical Summary **2007084TS**) by updating the existing Pontis Bridge Management System—used to recommend the repair or replacement of bridges—with a scheme that classifies steel bridges based on the frequency and severity of fracture and fatigue-sensitive details present in each bridge.

Another significant use of SRP funds in 2009 saved money by improving Mn/DOT construction management practices. This effort included studies to improve construction cost forecasting through after-the-fact evaluations (**Report 2009-11**), provide decision support as to the circumstances in which advance right-of-way acquisition is most cost-effective (**2009-07**) and evaluate the land-value impacts when a road is upgraded to help Mn/DOT better determine where, when and whether to build (**2009-16**).

Mn/DOT is making increased use of Transportation Research Synthesis reports to help focus research and avoid unnecessary duplication. These low-cost reviews of literature and/or practices will be used even more in 2010. In 2009, Mn/DOT sponsored these TRSs:

- Methods and Practices for Control of Canada Thistle (**TRS0901**—co-funded with LRRB)
- Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice (**TRS0902**—co-funded with State Planning & Research)
- Issues of Concern Related to Underground Infiltration Systems for Stormwater Management & Treatment (**TRS0903**)



Report 2009-13 established best-practice guidelines for concrete deck and crack sealing on Minnesota's bridges.



Mn/DOT funded research (**Reports 2009-37 and 2009-38**) to improve the efficiency of pile driving operations, enabling construction crews to build safe foundations for bridges with less expense.

FHWA State Planning and Research

State Planning and Research funds are received from the Federal Highway Administration for Mn/DOT planning and research activities. The most recent transportation authorization act—the Safe, Accountable, Flexible, Efficient Transportation Equity Act—requires that a minimum of 25 percent of these funds are to be used specifically for research (designated “SP&R Part II”) to address state-specific research needs, with the remaining portion going to planning, administration and other needs (“SP&R Part I”). We have provided information here only for Part II funds, though it should be noted that unlike most state research programs, Mn/DOT Research Services oversees Part I spending as well.

SP&R Part II funds can be used for participation in multi-state pooled fund efforts or in single-state efforts. Multi-state pooled funds allow Mn/DOT to multiply its research dollars, saving taxpayer money. SP&R funds enable Mn/DOT to invest in and pursue long-range strategies and research into innovative new technologies that might not otherwise be feasible. Some highlights of these efforts involve new pavement design testing at the MnROAD facility, intelligent compaction of soils, optimization of maintenance and construction techniques, and projects geared toward meeting regional (that is, the Midwest) and local needs. SP&R funds are often used to fund implementation and technology transfer efforts to ensure that developed innovations are understood and used by Mn/DOT districts and local governments.

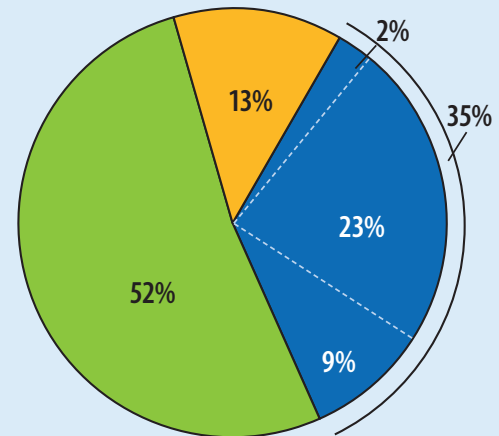
Research Services is responsible for the administration of the SP&R program. Deb Fick serves as the SP&R program administrator, managing funding requests from other offices for new and ongoing projects, monitoring program expenditures and developing an annual work program that includes salary cost estimates from various offices along with research project updates to meet FHWA requirements. She and other staff members serve as administrative liaisons for all SP&R projects.

National Cooperative Highway Research Program

The National Cooperative Highway Research Program receives 5.5 percent of all states’ SP&R Part II funding to feed the national need for research into highway planning, design, construction, operations and maintenance. This research includes the evaluation of fundamental new technologies and techniques, such as the move to Mechanistic-Empirical Pavement Design, and sharing best practices between states, as with NCHRP 08-62, “Transportation Performance Management Programs—Insight from Practitioners,” the panel chaired by Mark Larson, supervisor in the Performance, Planning and Measurement Unit of Mn/DOT’s Office of Investment Management. Mn/DOT is well-represented on panels for NCHRP projects as well as for other cooperative programs such as the Transit Cooperative Research Program and the Strategic Highway Research Program 2. See page 50 for details.

2009 SP&R Part II Funding Distribution

<ul style="list-style-type: none"> ■ Mn/DOT-led Multi-state Pooled Funds 13% \$390,000 ■ Participation in Other Multi-state Pooled Funds 52% \$1,571,825 ■ Single-state SP&R Projects 35% \$1,040,864 	<table border="0"> <tr> <td colspan="3">Program and Administrative Support:</td> </tr> <tr> <td style="padding-right: 20px;">Support:</td> <td style="padding-right: 20px;">9%</td> <td>\$277,914</td> </tr> <tr> <td>Implementation:</td> <td>23%</td> <td>\$694,661</td> </tr> <tr> <td>MnROAD:</td> <td>2%</td> <td>\$68,289</td> </tr> <tr> <td>Total:</td> <td></td> <td>\$2,626,863*</td> </tr> </table>	Program and Administrative Support:			Support:	9%	\$277,914	Implementation:	23%	\$694,661	MnROAD:	2%	\$68,289	Total:		\$2,626,863*
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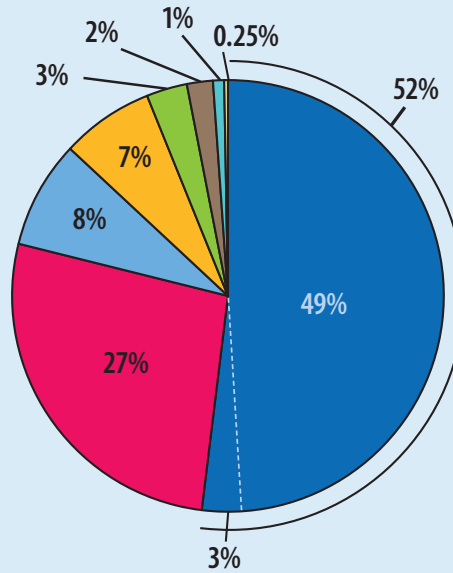


*Figures are rounded to the nearest dollar and percent.

2009 SP&R Part II Funding by Mn/DOT Strategic Research Area

■ Infrastructure Preservation	52%	\$1,357,851
Roads: 49%		\$1,287,839
Bridges: 3%		\$70,012
■ Congestion Management	27%	\$710,000
■ Traffic Safety	8%	\$202,845
■ Innovative Project Delivery	7%	\$190,514
■ Green Roads	3%	\$89,463
■ Organization Transformation	2%	\$45,000
■ Multi-modal Infrastructure	1%	\$25,000
■ Build Trust from Public and Legislature	0.25%	\$6,190

Total: \$2,626,863*



*Excludes administrative projects, but includes some projects without an assigned end-user product for which an associated research area could be determined.



SP&R funding provides increased opportunities to use the MnROAD cold-region testing laboratory, a unique platform for testing road-building materials and designs. MnROAD features two road segments—3.5 miles of mainline highway and 2.5 miles of low-volume roadway—divided into 52 test cells.

Leading Multi-State Collaborations

Mn/DOT has been a leader in multi-state pooled fund efforts, spearheading 12 pooled funds including investigations of Non-Intrusive Traffic Detection Technologies (TPF-5(171)), Intelligent Transportation Systems Across the Northwest Passage (TPF-5(190)) and, with the onset of 2010, the Clear Roads Winter Highway Operations Pooled Fund (TPF-5(218)).

Pooled Fund Highlights

Aurora Program, SPR-3(042)

An international partnership to develop road and weather information systems.

Founded in 1996, the Aurora program is an ongoing international partnership of transportation agencies, universities and weather services that collaborate on research, development, deployment and technology transfer in the field of road and weather information systems.

RWIS consists of a combination of technologies that include environmental stations around the state, which collect atmospheric weather data such as temperature and humidity, and roadside sensors, which collect information about pavement and underlying soil temperatures, water levels and icing. RWIS data is monitored and processed at a central location to provide real-time information about storms and pavement conditions, and to help forecast weather patterns. This information can be provided in turn to travelers via roadway warning systems, interactive 511 telephone systems and Web sites so drivers can make better decisions about when to travel and what routes to take. RWIS also helps agencies make more informed and proactive maintenance decisions—such as pretreating pavement surfaces to prevent icing—that are fine-tuned to current road conditions.

As part of this FHWA pooled fund study, Mn/DOT carries out research in collaboration with other partners on a range of issues, from the accuracy of RWIS sensors to their integration into a multiagency system. This program is improving the safety of road users in Minnesota and helps Mn/DOT significantly reduce the costs of winter maintenance and related activities. For more information and to download research papers, see www.aurora-program.org.

Roadside Safety Research Program, TPF-5(114)

Conducting roadside structure crash testing and promoting crashworthy design.

Because many state DOTs face similar roadside structure safety issues, Mn/DOT and a consortium of other states pooled their resources in 2005 to make research in this area less redundant and more cost-effective. Led by Washington State DOT, the Roadside Safety Research Program identifies common needs, solicits research proposals

and oversees the implementation of approved research projects.

Research addresses the design and testing of crash-worthy roadside structures, including bridge rails, highway guardrails, roadway transitions, median barriers and breakaway support structures. Projects also address the influence of highway features such as driveways, slopes, ditches, shoulders, medians and curbs on single-vehicle collisions.

In three years, the program has funded more than \$1 million in research for 14 projects performed by the Texas Transportation Institute. Member states also develop and fund their own projects, taking advantage of reduced overhead under the pooled fund agreement to make these projects more efficient and cost-effective. Many partner DOTs have sponsored full-scale crash testing of roadside features in accordance with FHWA's recommended procedures for evaluating their safety performance.

Research has also included in-service performance evaluation studies; computer simulations; clinical analyses; analysis of real-world crash data; cost/benefit analyses; and the development of guidelines for the use, selection and placement of roadside structures. By participating in this consortium, Mn/DOT has benefited from the research of other states and reduced the costs of its own roadside safety research. Funding for this project runs through 2011. For more information, see www.roadsidepooledfund.org.

Clear Roads Test and Evaluation of Materials, Equipment and Methods for Winter Maintenance, TPF-5(218) *continued from TPF-5(092)*

Real world testing of winter maintenance operations.

Clear Roads was established in 2004 to fund and oversee the field testing of winter maintenance materials, methods and equipment. The program has funded two to three research projects annually focused on identifying innovative solutions, evaluating their effectiveness for managing a range of winter conditions, and assessing their practicality and ease of use within varied highway maintenance organizational structures.

Since its inception, Clear Roads has grown from four to 18 member states, and is currently expanding its scope to focus on state agency needs, technology transfer and implementation, including support for staff in the field. As state DOTs aggressively pursue new technologies and practices for improving winter highway operations, this pooled fund project will support their evaluation in both the laboratory and the field to develop industry standards, performance measures and cost/benefit analyses, and practical field guides and training curricula. It will also support peer-to-peer exchanges and collaborative efforts between winter maintenance specialists, promote public education related to winter maintenance and winter driving safety, and survey states for best practices concerning operational issues.

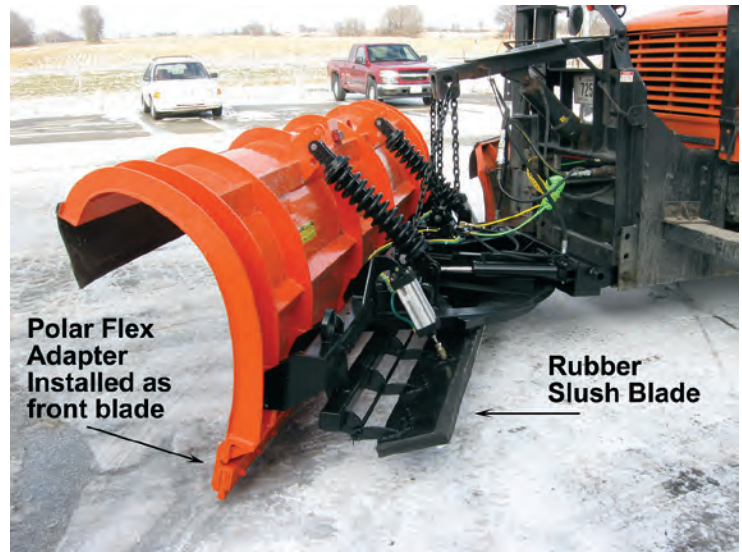
By pooling their resources and collaborating, Clear Roads participants not only avoid duplication of effort and benefit from each others' experience, but are able to conduct studies across a wider range of winter conditions than is possible for a single agency. As a consequence, this program helps agencies make informed operational and purchasing decisions to achieve the maximum return on their investments in materials, equipment and technology. For more information, see www.clearroads.org.

Midwest States Pooled Fund Crash Test Program, SPR-3(017)/TPF-5(193)

Innovative technologies to improve motorist safety during roadside crashes.

Now in its 16th year, this 13-member pooled fund program is based at the University of Nebraska's Midwest Roadside Safety Facility. The program is dedicated to making the roadside less hazardous to motorists by evaluating the performance and safety of standard roadside hardware designs used by various state highway agencies.

The program is also recognized as a global leader in the research, development and computer modeling of new roadside safety hardware. The MwRSF has developed numerous guardrail technologies, bridge railings, work-zone devices and other technologies that have been adopted nationwide and in some cases internationally. With funding from NCHRP, the MwRSF is currently developing guidelines and warrants for the use of roadside



Clear Roads recently funded the development of innovative prototype snowplows capable of tackling a range of winter road conditions using multiple plow blades. For more information, see www.clearroads.org/multiple-blade-plow-prototypes.html.

safety structures as well as performing a long-term accident investigation study to better understand the causes of injuries and fatalities in run-off-road crashes.

In the last decade, the program's efforts and new safety features have saved the lives of countless motorists across the nation. They have also improved the safety of drivers participating in high-speed racing events with the development of a safety feature now installed

on all NASCAR racing tracks. This technology, the Steel and Foam Energy Reduction barrier, has prevented serious injury in numerous severe impacts. For more information about this pooled fund and the MwRSF, see engineering.unl.edu/specialty-units/mwrsf/.



The MwRSF's SAFER barrier uses foam cushioning to make racetrack guardrail impacts safer. Indy Racing League Senior Technical Director Phil Casey has called it "the greatest achievement for safety in automobile racing that's been made."

Evaluation of Low Cost Safety Improvements, TPF-5(099)

Assessing the effectiveness of NCHRP-recommended highway safety strategies.

The goal of this program is to reliably estimate the effectiveness of strategies recommended by NCHRP for improving the highway safety. These recommendations are detailed in *NCHRP Report 500, Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*, a series of volumes that cover various kinds of highway crashes and factors contributing to them.

To develop these estimates, researchers are conducting scientifically rigorous before-and-after evaluations at sites where these NCHRP strategies are being implemented. Strategies include signage enhancements, left turn lane treatments, run-off-road crash countermeasures, curb visibility improvements and methods to slow traffic through small towns.

In March 2009, a fifth phase was added to this study to solicit volunteer states to build untested, low-cost safety countermeasures for evaluation.

With participation from 27 states, this pooled fund study will help achieve the shared national goal of USDOT, AASHTO and the Governors Highway Safety Association to reduce fatality rates and save lives. The cost/benefit analyses produced by this study will help state DOTs prioritize their safety improvements, depending on both circumstances and budget. For more information, see www.tfhrcc.gov/safety/evaluations/.

Transportation Management Center Pooled Fund Study, SPR-2(207)

Improving the operations of transportation management centers.

This pooled fund study serves as a forum for the FHWA and regional, state and local agencies to identify and address key issues and challenges common to the operation of transportation management centers. TMCs are used by public agencies to monitor and report on roadway and travel conditions, coordinate with local interests in response to changing conditions, and proactively manage and control traffic to mitigate the impacts of congestion and improve the reliability of travel. TMCs also

play a critical role in coordinating, supporting and sharing information concerning roadway and travel conditions with emergency services and the traveling public.

The program funds, oversees and disseminates the results of projects related to these issues, including improving the day-to-day operations of TMCs, enhancing their business management, managing their evolution, delivering roadway and travel condition information, hiring and managing staff, and improving knowledge and information sharing.

Since the study's inception in 2000, 27 projects have been completed, initiated or approved. Completed projects include the development of best practices for changeable message sign operations and messaging as well as manuals on TMC operations, staffing, business planning and performance monitoring. Ongoing projects cover topics such as driver use of real-time travel time information, human factors design guidelines and management of contractor services. Future projects will include integrating TMCs with law enforcement, TMC roles in emergency operations and highway advisory radio effectiveness. For more information, see tmcops.fhwa.dot.gov/overview.cfm.



Completed SP&R Reports

The following reports were published through Mn/DOT in 2009. They include multiple MnROAD products, some projects cooperatively funded with Mn/DOT's State Research Program and a Transportation Research Synthesis report.



2009-14: Implementation of Intelligent Compaction Performance Based Specifications in Minnesota

Project Cost: \$425,000

Performed by: Iowa State University **PI:** David White
TL: John Siekmeier **AL:** Clark Moe

Description: Investigators developed procedures for implementing intelligent compaction and light weight deflectometer equipment. The team also developed four IC specification options and facilitated a series of five training seminars for Mn/DOT staff and contractors. The project was co-funded by SP&R and the Mn/DOT Office of Materials. A Technical Summary of this report is included in this publication.

2009-22: 2008 MnROAD Phase II Construction Report

Project Cost: N/A (covered by Mn/DOT Office of Materials funding)

Performed by: Mn/DOT Office of Materials
PI: Ann Johnson, Tim Clyne, Ben Worel

Description: This report documents MnROAD construction projects completed during the 2008 construction season,

including the creation of new test cells and reconstruction of 24 test cells on MnROAD's mainline and low-volume road sections. New test cells included various asphalt and concrete pavement materials as well as aggregate base materials; they were constructed to evaluate both new construction and rehabilitation techniques. Project cost for construction, research, instrumentation and administration totaled \$10.9 million; work activities represented research pursuing both national and regional interests. Core research areas that guided Phase II construction were mechanistic design, innovative construction, preventive maintenance, recycled materials, pavement rehabilitation, surface characteristics and other nonpavement research.

2009-26: Demonstration of Concrete Maturity Test Process on the TH-694/TH-35E Interchange—Unweave the Weave

Project Cost: N/A (funded as part of a larger, ongoing effort)

Performed by: Mn/DOT Office of Materials
PI: Bernard Izevbekhai

Description: A maturity protocol allows a more precise identification of the time when a pavement has gained sufficient strength to be opened to traffic. This protocol allows traffic to be regulated to protect the integrity of the pavement while simultaneously streamlining construction operations by avoiding excessive initial cure periods. Through field testing and data analysis, investigators developed maturity strength curves for the majority of the paving mixes used by Mn/DOT and test maturity meter implementation on several projects to observe potential difficulties and successes with their use.

2009-30: Ultrathin Bonded Wearing Course Performance Update, Minnesota

Project Cost: N/A (covered by Mn/DOT Office of Materials funding)

Performed by: Mn/DOT Office of Materials
PI: Ahmed Ali Ahmed

Description: In the summer of 2004 and 2005, test sections of an ultrathin bonded wearing course—a method of extending pavement life for asphalt and concrete road—were constructed to demonstrate the effectiveness of this type of design. The study found that the ride quality index

improved with this design without any major distresses, making this technology promising for future pavement design.

2009-35: Procedures to Use and Manage IC Data in Real Time

Project Cost: \$84,457

Performed by: CNA Consulting Engineers, Inc.

PI: Lee D. Petersen

TL: Rebecca Embacher, Tim Andersen **AL:** Clark Moe

Description: Investigators developed software and processes for storing, manipulating and visualizing large quantities of data produced by intelligent compaction-equipped rollers so that the data can be used for quality control and assurance. The software enables researchers to better understand the compaction process, to evaluate the uniformity of compaction across a structure by identifying areas of weak and strong compaction, and to direct field personnel where to conduct quality control assurance using in situ measurement devices. A Technical Summary of this report is included in this publication.



2009-42: Asphalt Mixture and Binder Fracture Testing for 2008 MnROAD Construction

Project Cost: N/A (covered by Mn/DOT Office of Materials funding)

Performed by: Mn/DOT Office of Materials

PI: Mihai Marasteanu

Description: This report summarizes the results of an experimental effort to characterize the low-temperature behavior of asphalt mixtures and binders from recently reconstructed MnROAD cells. In-depth analysis of the data will be accomplished in several subsequent research projects.

2007-084, Implementation of Steel Bridge Maintenance Planning

Project Cost: \$35,630

Performed by: University of Minnesota

PI: Arturo Schulz

TL: Jim Pierce

AL: Bruce Holdhusen

Description: This project implemented research that classifies steel bridges based on the frequency and severity of fracture and fatigue-sensitive details that are present in each bridge. The gross ranking of bridges with high, medium or low need for preventive maintenance or special inspection will be stored in Pontis, Mn/DOT's bridge management database, for use by bridge inspectors and those responsible for managing Minnesota's bridges. The project was co-funded by SP&R and the State Research Program. A Technical Summary of this report is included in this publication.

TRS0902: Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice

Project Cost: N/A (covered by Technology Transfer funding)

Performed by: CTC & Associates LLC

PI: Pat Casey, Chris Kline

TL: Linda Taylor

AL: Jake Akervik

Description: Mn/DOT is developing an anti-icing guide for use by front-line supervisors and managers to better manage winter operations and by operators to assist them in effectively performing snow and ice control duties. This Transportation Research Synthesis constitutes a step in preparation for that guide. It reviews existing literature to identify existing anti-icing practices, field strategies and procedures, and application rates. It also includes reviews of 12 transportation agencies' anti-icing guidelines and procedures to identify current patterns of practice. The project was co-funded by SP&R and the State Research Program.

Single-state SP&R Projects

The following single-state SP&R projects were active in 2009. The Amount Paid indicates the amount paid by Mn/DOT against invoices through November. We have ordered these projects according to their associated Mn/DOT Strategic Focus Area. Administrative projects not specific to one of these areas are given at the end of the list.

Innovative Project Delivery

MPR-6(009): TH36 Full Closure Impacts—Highways for Life Corridor: To Close or Not to Close

Funded by: SP&R/SRP

Total Cost: \$109,890 **Amount Paid:** \$95,605

Performed by: University of Minnesota **PI:** John Hourdos
TL: Chris Roy, Colleen Von-Wagner **AL:** Bruce Holdhusen

Description: This project will measure the benefits of full road closure during construction by using an actual ongoing project as a test case: Highway 36 was selected for full closure to construct a project in North St. Paul. In addition to producing a guide for engineers, this project will provide valuable data for the cost/benefit analysis and effective traffic management for future projects.

Status: The project team evaluated traffic operations alternatives in the project area and began work on a full closure decision assistance guide. A full closure workshop was conducted in April 2009.

Start Date: 4/5/2007 **Projected End Date:** 1/31/2010

Work Complete: 81%

MPR-6(033): TRACS Research and Implementation Project

Funded by: SP&R/SRP

Total Cost: \$310,000 **Amount Paid:** \$246,843

Performed by: Project Information Services

PI: L. Tim Malagon

TL: Thomas Wiener **AL:** Clark Moe

Description: This project will evaluate available construction project management software with a focus on TRACS software. Stakeholder interviews will identify barriers to its implementation and use. A detailed review of the software and its capabilities will be conducted, and the project team will assist in developing and delivering training and presentations to Mn/DOT and state industry groups.

Status: TRACS software implementation went well. All Mn/DOT projects after January 1, 2009, use TRACS in some capacity, with the Metro district utilizing the most.

Increased use of other modules will occur as the training curve allows.

Start Date: 3/12/2008

Projected End Date: 6/30/2010

Work Complete: 80%



MPR-6(033): Construction Project Management Software Evaluations

Funded by: SP&R/SRP

Total Cost: \$138,697 **Amount Paid:** \$0

Performed by: Minnesota State University, Mankato

PI: James Wilde

TL: Thomas Wiener **AL:** Clark Moe

Description: This project will evaluate available construction project management software, with a focus on TRACS software. Stakeholder interviews will identify barriers to its implementation and use. A detailed review of the software and its capabilities will be conducted, and the project team will assist in developing and delivering training and presentations to Mn/DOT and state industry groups.

Status: Project evaluation is under way and a draft summary report was delivered in December 2009. Seven other tasks are scheduled to be completed by October 2011.

Start Date: 9/24/2008

Projected End Date: 10/31/2011

Work Complete: 0%

Infrastructure Preservation—Roads

MPR-6(012): Development of New Test Roller Equipment and Construction Specs for Subgrade Compaction Acceptance

Funded by: SP&R/SRP **Total Cost:** \$253,300

Amount Paid: \$86,684

Performed by: Minnesota State University, Mankato

PI: Aaron Budge

TL: Tim Anderson **AL:** Dan Warzala

Description: The purpose of this project is to develop a more effective test roller system. New specifications will be developed that improve the existing test roller specs and account for variations in projects (such as the type of subgrade or the thickness of the base material).

Status: Weather and contract issues have delayed equipment testing. However, researchers have validated operation of the new system's hardware and software when plastic material was used with the deflection model. The other two projects are granular material and have not been tested.

Start Date: 1/24/2008 **Projected End Date:** 5/31/2010

Work Complete: 40%

MPR-6(016): Performance of Thin Unbonded Concrete Overlays on High Volume Roads

Funded by: SP&R/SRP

Total Cost: \$126,100 **Amount Paid:** \$0

Performed by: Mn/DOT Office of Materials

PI: Mark Watson

TL: Bernard Izevbekhai **AL:** Bruce Holdhusen

Description: The primary objective of this research is to develop better distress and life prediction models for thin unbonded concrete overlays over older concrete pavements. Researchers will also study the behavior of these overlays with regard to maturity, slab warp and curl thermal expansion, and repair techniques.

Status: Researchers have completed a literature review, created a test cell layout and performance monitoring plan, and constructed a test section. In November 2009, they began conducting seasonal monitoring for the first-year performance report.

Start Date: 12/29/2008 **Projected End Date:** 2/28/2014

Work Complete: 0%

MPR-6(021): Pavement Surface Characteristics Concrete New Construction (MnROAD Studies)

Funded by: SP&R

Total Cost: \$150,000 **Amount Paid:** \$0

Performed by: Mn/DOT Office of Materials

PI: Bernard Izevbekhai

TL: Benjamin Worel **AL:** Bruce Holdhusen

Description: This study focuses on automobile tires and pavement surface characteristics, including ride quality, friction, hydroplaning potential, splash and spray, texture and noise. Testing is performed on various texturing configurations in the Minnesota Road Research Facility Low Volume Road and the mainline. Comparative analysis may introduce data from cells or test sections outside of MnROAD.

Status: The MnROAD test cell and instrumentation design for this project was completed in fall 2007. Researchers performed preconstruction noise testing and obtained preconstruction ride quality measurements. Preconstruction friction and texture measurements have begun.

Start Date: 9/24/2009 **Projected End Date:** 4/30/2011

Work Complete: 10%



MPR-6(022): INV 864: Recycled Asphalt Pavements

Funded by: LRRB/FHWA

Total Cost: \$200,000 **Amount Paid:** \$25,000

Performed by: Mn/DOT Office of Materials

PI: Eddie Johnson

TL: Roger Olson **AL:** Bruce Holdhusen

Description: This project will study the performance of recycled asphalt pavement under controlled testing conditions. The asphalt concrete test sections will have similar structural designs and contain 30 percent RAP but vary by

binder grade and fractionated RAP content. In 2009 three new mix designs were added: warm mix with RAP, Superpave with no RAP and Superpave with 20 percent RAP.

Status: Researchers constructed test sections and incorporated RAP at MnROAD. Sampling included component materials, RAP mixtures obtained at the plant and cores obtained from test sections. Lab testing on construction samples also started in 2009.

Start Date: 1/4/2008 **Projected End Date:** 12/31/2012

Work Complete: 11%

MPR-6(029): INV 868: HMA Surface Characteristics

Funded by: LRRB/SP&R

Total Cost: \$300,000 **Amount Paid:** \$38,823

Performed by: Mn/DOT Office of Materials

PI: Timothy Clyne

TL: Greg Johnson **AL:** Bruce Holdhusen

Description: This study focuses on key pavement surface characteristics like noise and friction while also studying their relationship to ride quality, texture and mixture durability. Researchers will conduct statistical pass-by noise monitoring and data analysis to make relative comparisons of pavement surfaces on the interstate test sections at MnROAD.

Status: This project is ongoing. Surface characteristic (noise and smoothness) data were collected in 2009 but have not been reported.

Start Date: 9/18/2007 **Projected End Date:** 11/30/2012

Work Complete: 33%

MPR-6(031): Concrete Pavement Optimization, Determining the Lower Threshold of Slab Thickness for High Volume Roadways

Funded by: SP&R **Total Cost:** \$126,100

Amount Paid: \$0

Performed by: Mn/DOT Office of Materials

PI: Thomas Burnham

TL: Bernard Izevbekhai **AL:** Bruce Holdhusen

Description: This project will develop better distress and life prediction models for more optimized (thinner) concrete pavements. Secondary objectives include understanding the behavior of these pavements with regard to maturity, slab warp and curl, thermal expansion and repair techniques. Researchers will conduct seasonal load response

testing and monitor the field performance of an instrumented variable thickness concrete pavement test cell.

Status: This project is ongoing. Findings will be reported when pavement failure occurs.

Start Date: 1/3/2008

Projected End Date: 7/31/2014

Work Complete: 0%

MPR-8(004): Development of a Concrete Maturity Test Protocol

Funded by: SP&R/SRP

Total Cost: \$113,952 **Amount Paid:** \$42,720

Performed by: Minnesota State University, Mankato

PI: James Wilde

TL: Ryan Rohne **AL:** Sandy McCully

Description: The overall objective of this project is to develop strength-maturity relationships in concrete that will allow contractors, field personnel and materials engineers to estimate the strength of high-pozzolan/SCM and low-w/c concrete pavement mixes in the field, with reduced sampling and testing of concrete.

Status: Researchers reviewed current research and purchased equipment. They also developed a testing method for maturity testing on construction projects. A TAP meeting was held in October 2009.

Start Date: 4/2/2009

Projected End Date: 9/30/2012

Work Complete: 20%

MPR-9(001): Stabilized Full Depth Reclamation (SFDR) Implementation

Funded by: SP&R/SRP **Total Cost:** \$25,000

Amount Paid: \$0

Performed by: American Engineering Testing, Inc.

PI: Dave Rettner

TL: John Hager, Steven Adamsky **AL:** Clark Moe

Description: This project will generate two mix designs for full depth reclamation projects to be constructed during 2010. These designs will use three asphalt emulsions and will, if successful, aid in the standardization of Mn/DOT's FDR procedures.

Status: Work on this project is just beginning. In addition to the funding garnered from SP&R and the State Research Program, \$200,000 has been approved through the Destination Innovations fund.

Start Date: 9/18/2009

Projected End Date: 7/31/2010

Work Complete: 0%

Infrastructure Preservation—Bridges

MPR-9(002): Concrete Bridge Deck Crack Sealant Evaluation and Implementation

Funded by: SP&R/SRP

Total Cost: \$80,918 **Amount Paid:** \$4,358

Performed by: Braun Intertec Corporation **PI:** Rachel Detwiler

TL: James Lilly **AL:** Dan Warzala

Description: This study will examine the performance of the best candidate crack-repair materials in Mn/DOT bridges. The scope of work includes field testing, evaluation of crack sealant products, depth of penetration, product effectiveness and performance validation. A best practices manual will be created for Mn/DOT practitioners.

Status: In 2009, researchers selected bridges, products and test methods. Because of bad weather in 2009, testing of crack sealers was postponed until June 2010.

Start Date: 9/30/2009 **Projected End Date:** 3/31/2013

Work Complete: 0%

Traffic Safety

MPR-6(014): Evaluation of SafeLane Overlay System for Crash Reduction on Bridge Deck Surfaces, Years 2 & 3

Funded by: SP&R/SRP

Total Cost: \$35,400 **Amount Paid:** \$14,570

Performed by: University of Minnesota–Duluth

PI: John Evans

TL: Farideh Amiri **AL:** Nelson Cruz



Description: This research will evaluate the product performance, safety and maintenance benefits of a Cargill SafeLane anti-icing pavement overlay system. Researchers will conduct field tests and evaluate accident reduction statistics. They will also perform a benefit/cost analysis and evaluate safety data from SafeLane installations completed during the summer of 2007.

Status: In 2009, the project team focused on collecting and analyzing results from laboratory and field tests, crash data on SafeLane installations and observations from plow operators.

Start Date: 2/29/2008 **Projected End Date:** 8/31/2010

Work Complete: 38%

MPR-8(002): Vehicle Telematics for Novice Teenage Driver Support System—Smart Phone Based Novice Teenage Driver Support

Funded by: SP&R

Total Cost: \$500,000 **Amount Paid:** \$65,284

Performed by: University of Minnesota **PI:** Max Donath

TL: Susan Sheehan **AL:** Dan Warzala

Description: This project will develop a Teen Driver Support System demonstration based on smart-phone technology that will prevent vehicle operation when alcohol is detected or seat belts are unfastened. Various on-board technologies will communicate with in-vehicle subsystems to provide real-time feedback to teen drivers about unsafe or illegal activities such as speeding and stop sign noncompliance. **Status:** Researchers proposed an interface strategy for the TDSS and began to develop the system. They also created a conceptual model of a revised graduated driver licensing program.

Start Date: 12/9/2008 **Projected End Date:** 5/31/2011

Work Complete: 13%

Responding to Customers and Stakeholders

MPR-6(007): Hear Every Voice Implementation & Training

Funded by: SP&R/SRP/Other state funds

Total Cost: \$230,798 **Amount Paid:** \$86,136

Performed by: University of Minnesota **PI:** Jim Grothaus

TL: Scott Bradley **AL:** Becky Lein

Description: The overall objective of this project is to develop, deploy and evaluate trainings based on the new Mn/DOT

Public Involvement Guidance Document, “Hear Every Voice II.” These activities will help Mn/DOT achieve compliance with the new federal SAFETEA-LU requirements while also achieving benefits and cost-effectiveness in planning and program development.

Status: In 2009, the project team implemented and evaluated selected courses for the statewide Mn/DOT Public Involvement Plan, and began offering coaching and technical assistance services. The university conducted a usability test of the HEV Web site and provided recommendations for enhancements.

Start Date: 7/16/2007 **Projected End Date:** 5/31/2010

Work Complete: 40%

Green Roads

MPR-6(032): Designing Site-Specific Roadside Prairie or Grassland Seed Mixes

Funded by: SP&R/SRP

Total Cost: \$125,000 **Amount Paid:** \$85,345

Performed by: The Kestrel Design Group, Inc.

PI: L. Peter MacDonagh

TL: Kenneth Graeve **AL:** Shirlee Sherkow

Description: Researchers will review information about site-specific grassland seed mixes and apply it to roadside problem solving for new projects and for rehabilitation. They will develop a model for defining site-specific seed mixes that can be used by other state DOTs and road agencies, and they will produce a how-to manual for developing site-specific Minnesota native grassland seed mixes.

Status: The contractor created and documented a method to develop site-specific seed mixes for use on highways and other projects. The contractor also developed seed standards and uniform seed mixes that can be used over large portions of the state for conservation purposes such as erosion control and stormwater treatment.

Start Date: 10/23/2008 **Projected End Date:** 3/31/2010

Work Complete: 68%

MPR-8(006): Maintenance Anti-Icing Study (Market Research)

Funded by: SP&R

Total Cost: \$99,896 **Amount Paid:** \$15,095

Performed by: EVS **PI:** Paul Keranen

TL: Linda Taylor **AL:** Bruce Holdhusen

Description: The purpose of this study is to more fully understand the practices and procedures for deploying anti-icing techniques throughout the state. Researchers will survey maintenance management, supervisors and front-line operators, and use the results to inform an anti-icing manual that will address various conditions (weather, roadway types, level of service, climatological conditions and traffic volumes).

Status: Researchers completed the study design and developed a series of survey questions. Programming and data collection were completed, and a summary of findings was delivered.

Start Date: 6/12/2009 **Projected End Date:** 4/30/2011

Work Complete: 0%

MPR-8(006): Anti-icing Technology Implementation

Funded by: SP&R

Total Cost: \$99,896 **Amount Paid:** \$15,095

Performed by: EVS **PI:** Paul Keranen

TL: Ferideh Amiri **AL:** Bruce Holdhusen

Description: The goals of this project are to develop an anti-icing implementation plan that assesses the current state of anti-icing within each district; identifies resource gaps and needs; and creates a plan for a uniform, more consis-



tent level of anti-icing statewide. Guidelines for effective anti-icing based upon research and the experience of other DOTs and districts will be created.

Status: In 2009, researchers conducted a literature review of anti-icing practices.

Start Date: 6/12/2009 **Projected End Date:** 4/30/2011

Work Complete: 0%

Administrative

MPR-6(003): Library Information Resources Update

Funded by: SP&R/SRP

Total Cost: \$23,130 **Amount Paid:** \$23,130

Performed by: Lowell Benson **PI:** Lowell Benson

TL: James Byerly **AL:** Sheila Hatchell

Description: The Mn/DOT Library staff and management keep library resources current so that users can keep pace with innovations that emerge from various research projects. Library services are available to Mn/DOT employees as well as county engineers; city engineers; and numerous consultants who are working on local, state and national projects.

Status: The Library staff has completed numerous tasks for this project, including reviewing the publication dates of its current collection of handbooks, manuals and other resource materials followed by an Internet search to determine if newer editions are available. The staff has also developed an ordering process for its print and electronic collections.

Start Date: 3/30/2009 **Projected End Date:** 7/31/2009

Work Complete: 100%

MPR-6(003): Strategic Program Development

Funded by: SP&R/SRP

Total Cost: \$140,690 **Amount Paid:** \$139,283

Performed by: Trissential **PI:** Steve Beise

TL: Linda Taylor **AL:** Cory Johnson

Description: This project involves working with Research Services to determine and document the workflows and handoff points for managing research contracts involving numerous roles and project phases, for the purpose of optimizing the new ARTS database to support Research Services activities.

Status: Researchers have begun the next phase of this project, which includes developing the process for Strategic Program Development program management and the financial services section.

Start Date: 8/6/2007 **Projected End Date:** 4/30/2009

Work Complete: 100%

MPR-6(003): Innovation Program Development

Funded by: SP&R/SRP **Total Cost:** \$100,000

Amount Paid: \$90,090

Performed by: Dave Johnson **PI:** Dave Johnson

TL: Linda Taylor **AL:** Cory Johnson

Description: This project focuses on Mn/DOT's strategic vision for research and helps Research Services operate more efficiently and effectively in a strategically focused environment. The current work plan provides expertise and resources to assist Research Services in developing and carrying out business plans and transitioning Mn/DOT's research tracking system to ARTS NG.

Status: The major objectives of this project are complete, including the successful transition to ARTS NG; the development of research roadmaps and new roles and procedures; the creation of a Research Services transition business plan and a library business plan; and delivery of a final report detailing the procedures.

Start Date: 10/1/2008 **Projected End Date:** 11/30/2010

Work Complete: 83%

MPR-6(004): Implementation & Closeout Program Administration Support

Funded by: SP&R

Total Cost: \$97,500 **Amount Paid:** \$67,500

Performed by: Micky Ruiz **PI:** Micky Ruiz

TL: Jake Akervik **AL:** Clark Moe

Description: Research Services is transitioning from a system that determines research and implementation needs annually to a strategic system of developing roadmaps that determine needs based on research and implementation gaps. The new initiative comprises consultant contracts that will establish a foundation by which the Mn/DOT Research Program will be managed in the future.

Status: Team members developed a "triage" system that looked at completed projects in relationship to the development of an end-user product. They categorized products by development stage (knowledge development, product development and product deployment) and determined which products were ready to move forward. Staff assisted with implementation plans and funding requests for these products.

Start Date: 5/30/2008 **Projected End Date:** 1/31/2010

Work Complete: 90%

MPR-6(004): Investigation & Evaluation of Closeout Memo Data for the Development of Additional Performance Measures

Funded by: SP&R

Total Cost: \$83,490 **Amount Paid:** \$26,978

Performed by: William Bunde **PI:** William Bunde

TL: Cory Johnson **AL:** Clark Moe

Description: This project provided expertise and resources to help Research Services review current procedures and processes for evaluating Mn/DOT research and implementation programs; develop, track and report performance and process measures; and where necessary, recommend and develop new research process and outcome measures.

Status: Project team members identified successful research projects and shared these findings with AASHTO RAC Region 3 in August 2009. They identified two projects—Use of Two-Way Left Turn Lanes and Use of Foamed Asphalt—for potential benefit/cost analysis. They also used the Automated Research Tracking System to align Mn/DOT research with Research Services' eight strategic focus areas.

Start Date: 1/30/2008 **Projected End Date:** 3/31/2010

Work Complete: 80%

MPR-6(004): Implementation & Closeout Program Administration Support

Funded by: SP&R

Total Cost: \$39,600 **Amount Paid:** \$18,535

Performed by: Darlene Gorrill Inc. **PI:** Darlene Gorrill

TL: Jake Akervik **AL:** Clark Moe

Description: Research Services is developing a streamlined technology transfer process to support a more strategically focused research program that integrates high-level strategies with operational-level goals. Activities will include communications and outreach with other technology transfer efforts; departmentwide training; and creation of roadmaps that identify gaps in research and implementation.

Status: Work during the year included completing remaining closeout memos for 2006 projects; streamlining the closeout memo format for upcoming projects; writing brief updates of 2008 projects; completing several end-user project proposals; and writing an Innovation Update on intelligent compaction.

Start Date: 4/28/2008 **Projected End Date:** 1/31/2010

Work Complete: 47%

MPR-6(005): Research Management System—Phase I

Funded by: SP&R/SRP

Total Cost: \$209,000 **Amount Paid:** \$171,200

Performed by: Archwing Innovations, LLC

PI: Ryan Anderson

TL: Cory Johnson **AL:** Cory Johnson

Description: The purpose of this project is to enhance the functionality and technology platform of the Automated Research Tracking System, which tracks projects, contracts, implementation and funding. A new application—the Next Generation of ARTS—will replace the current version.

Status: Project portfolio management processes and changes in the ARTS application have enhanced decision making for viable projects as early as possible in their life cycle. The new application is Web-based and can be accessed remotely.

Start Date: 1/2/2008 **Projected End Date:** 4/30/2009

Work Complete: 100%

MPR-6(005): Next Generation of ARTS Tech Support and Maintenance Services

Funded by: SP&R/SRP

Total Cost: \$19,000 **Amount Paid:** \$10,000

Performed by: Archwing Innovations, LLC

PI: Ryan Anderson

TL: Nelson Cruz **AL:** Cory Johnson

Description: The primary goals of this project are to provide technical support and maintenance services for three Web-based applications of the current Next Generation of Automated Research Tracking System. Project activities include training and knowledge transfer to Mn/DOT staff.

Status: This project is ongoing. The consultant will continue to troubleshoot any problems and make minor changes along with enhancements to the new ARTS program.

Start Date: 5/13/2009 **Projected End Date:** 4/30/2010

Work Complete: 52%

MPR-6(019): Technology Transfer Material Development—Phase II**Funded by:** SP&R/SRP**Total Cost:** \$99,954 **Amount Paid:** \$99,949**Performed by:** CTC & Associates LLC **PI:** Patrick Casey**TL:** Cory Johnson **AL:** Jake Akervik

Description: Mn/DOT supports the continued development of outreach materials that market the products and services of Research Services and the Local Road Research Board. Through various publications, reports and technical transfer materials, Research Services communicates the findings of research results and conveys the services it provides.

Status: By February 2009, the contractor had delivered online versions of the *Mn/DOT Research Services 2008 Annual Report* and *At-A-Glance*, and had begun writing Technical Summaries.

Start Date: 4/29/2008 **Projected End Date:** 1/31/2010**Work Complete:** 100%**MPR-6(019): Technology Transfer Material Development—Phase III****Funded by:** SP&R/SRP**Total Cost:** \$99,023 **Amount Paid:** \$78,040**Performed by:** CTC & Associates LLC **PI:** Patrick Casey**TL:** Cory Johnson **AL:** Jake Akervik

Description: Mn/DOT supports the continued development of outreach materials that market the products and services of Research Services and the Local Road Research Board. Through various publications, reports and technical transfer materials, Research Services communicates the findings of research results and conveys the services it provides.

Status: The contractor delivered 38 Technical Summaries and 25 project evaluations covering 2009 research, and drafted 18 additional summaries with evaluations to complete all 2009 work for inclusion in the *Mn/DOT Research Services 2009 Annual Report*. New procedures were developed for project evaluations and document tracking and transmission. The contractor held a 2009 planning session with Mn/DOT staff in the spring.

Start Date: 2/24/2009 **Projected End Date:** 1/31/2010**Work Complete:** 90%**MPR-6(019): Technology Transfer Material Development—Phase IV****Funded by:** SP&R/SRP**Total Cost:** \$99,981 **Amount Paid:** \$3,891**Performed by:** CTC & Associates LLC **PI:** Patrick Casey**TL:** Cory Johnson **AL:** Jake Akervik

Description: The focus of this project is to produce materials created for 2008's year-end reporting. It also provides Research Services and the Local Road Research Board with additional technical transfer materials to communicate the results of Mn/DOT's federal- and state-funded research efforts to department staff, city and county employees, and other stakeholders.

Status: Work on this contract began with a pilot Management Update publication delivered in October. A guide to the 2009 Transportation Research Board meeting listing presentations by Mn/DOT-associated participants was delivered in December along with versions of the *Research Services At-A-Glance* and *LRRB At-A-Glance* publications. Planning and initial work started on the *Annual Report*.

Start Date: 9/24/2009 **Projected End Date:** 4/30/2011**Work Complete:** 10%**MPR-9(008): Mn/DOT's 2009 Peer Exchange—Quantifying and Communicating the Value of Research****Funded by:** SP&R**Total Cost:** \$4,635 **Amount Paid:** \$0**Performed by:** CTC & Associates LLC **PI:** Patrick Casey**TL:** Linda Taylor **AL:** Linda Taylor

Description: Mn/DOT will hosted a value of research workshop and peer exchange to encourage effective communication and information exchange about transportation research and practices among state DOTs.

Status: Research Services hosted a workshop and peer exchange November 2-4, 2009. Representatives from eight state DOTs, two Minnesota universities and FHWA-Minnesota joined representatives from Mn/DOT to learn about effective strategies for communicating the value of transportation research and to share best practices.

Start Date: 10/5/2009 **Projected End Date:** 1/31/2010**Work Complete:** 95%

Mn/DOT-led Multi-state Pooled Fund Projects

Minnesota leads multi-state pooled funds in the areas of infrastructure preservation (roadways) and congestion management. Some of these pooled funds also have applicability to other Mn/DOT strategic research areas; for example, Clear Roads serves to protect the traveling public (Traffic Safety) and address groundwater/anti-icing issues (Green Roads).

Infrastructure Preservation—Roads

TPF-5(129): Recycled Unbound Pavement Materials (MnROAD Study)

Number of Participating States: 6

URL: www.pooledfund.org/projectdetails.asp?id=361&status=4

Funded by: SP&R/SRP Total Cost: \$882,352

MN Paid in 2009: \$15,000

Performed by: UW–Madison PI: Tuncer Edil

TL: Andrew Eller AL: Nelson Cruz

Description: This study will monitor the performance of several test cells constructed with recycled materials in the granular base layers, including blended with virgin materials and 100 percent recycled asphalt and concrete pavement materials. Material properties will be used to verify mechanistic-empirical design inputs, especially variations with changing seasons and moisture regimes.

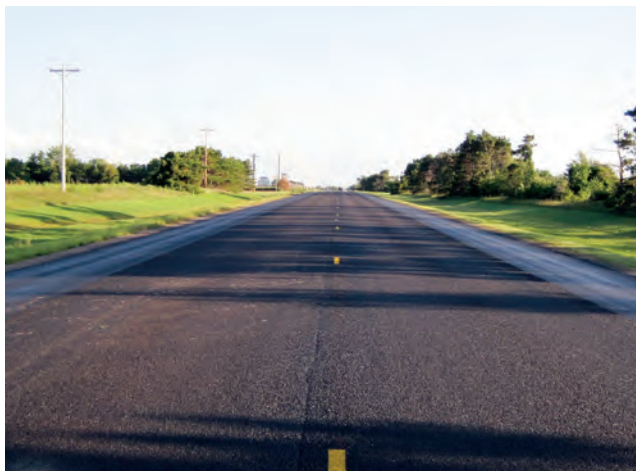
Status: A pooled fund teleconference was held April 3, 2009, while PIs met in person at Mn/DOT. Representatives from participating states provided pavement samples (including four samples related to the MnROAD test facility) that are being tested for various index and structural properties.

Testing to determine compaction characteristics, grain size distribution and resilient modulus is under way.

Start Date: 2007

Projected End Date: 2011

Work Complete: 20%



TPF-5(132): Investigation of Low Temperature Cracking in Asphalt Pavements, Phase II

Number of Participating States: 7

URL: www.pooledfund.org/projectdetails.asp?id=395&status=4

Funded by: SP&R/SRP Total Cost: \$420,000

MN Paid in 2009: \$20,000

Performed by: University of Minnesota

PI: Mihai Marasteanu

TL: Ben Worel AL: Bruce Holdhusen

Description: Phase I of this study looked at developing a fracture mechanics-based specification for a better selection of asphalt binders and mixtures with resistance to crack formation and propagation. In Phase II, researchers will validate the laboratory test procedures, models and pavement design procedures from Phase I by monitoring two new test sections at MnROAD.

Status: A TAP meeting was held November 18, 2009, at Mn/DOT. A literature review is complete, more than 75 percent of the lab testing is complete (Task-2), and researchers have updated a prediction model (TC Model). The final project output will consist of a two-tiered implementation system and will include individual state test results, costs and recommendations for selecting a testing protocol.

Start Date: 2007

Projected End Date: 2011

Work Complete: 30%

TPF-5(134 4): PCC Surface Characteristics—Rehabilitation (MnROAD Study)

Number of Participating States: 3

URL: www.pooledfund.org/projectdetails.asp?id=363&status=4

Funded by: SP&R/SRP Total Cost: \$275,000

MN Paid in 2009: \$15,000

Performed by: Mankato State University PI: W. James Wilde

TL: Bernard Izevbekhai AL: Bruce Holdhusen

Description: To create smooth pavements, researchers need to quantify the effects of pavement performance parameters. This project will provide data that will optimize pavement

quietness, friction, texture and ride. Researchers will determine to what degree total noise is generated by tire-pavement interactions, and they will develop a prediction of noise level based on grinding techniques.

Status: A draft report for Task 1 (review, revise and finalize diamond grinding construction report) is complete. A TAP meeting was held in June. Summer and fall measurements were taken.

Start Date: 2007 **Projected End Date:** 2010

Work Complete: 15%

TPF-5(148): The Effects of Implements of Husbandry “Farm Equipment” on Pavement Performance (MnROAD Study)

Number of Participating States: 6

URL: www.pooledfund.org/projectdetails.asp?id=375&status=4

Funded by: SP&R/SRP

Total Cost: \$433,000 **MN Paid in 2009:** \$0

Performed by: University of Minnesota

PI: W. Lev Khazanovich

TL: Shongtao Dai **AL:** Bruce Holdhusen

Description: This study will compare pavement response under various types of agricultural equipment (including the impacts of different tires and additional axles) to the response under a typical five-axle tractor-trailer, allowing policy and design decisions to be driven by direct experimental results rather than by models.

Status: Tests were done in spring and fall 2009. Cell83 WB (westbound) failed during the spring testing, and Cell83 EB (eastbound) failed during fall testing. A panel meeting was held in July 2009 and interim analysis was presented.

Start Date: 2007 **Projected End Date:** 2010

Work Complete: 40%

TPF-5(149): Design and Construction Guidelines for Thermally Insulated Concrete Pavements (MnROAD Study)

Number of Participating States: 5

URL: www.pooledfund.org/projectdetails.asp?id=376&status=4

Funded by: SP&R/SRP

Total Cost: \$455,000 **MN Paid in 2009:** \$20,000

Performed by: University of Minnesota

PI: W. Lev Khazanovich

TL: Tim Clyne

AL: Nelson Cruz

Description: Researchers will perform life cycle cost analysis comparisons and develop design and construction guidelines for thermally insulated concrete pavement. Additional objectives include validating the structural and climatic models of the Mechanistic-Empirical Pavement Design Guide for asphalt overlays, and determining the MEPDG's applicability for designing TICPs.

Status: Researchers submitted a report about the design and construction of composite pavement systems, and an analysis of the economically viable design solution and corresponding design lives. They also conducted a comprehensive sensitivity study of the EICM model; developed a data quality check procedure; and began to incorporate the CalME rutting and reflective cracking models into the MEPDG framework.

Start Date: 2007

Projected End Date: 2011

Work Complete: 30%

TPF-5(153): Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements (MnROAD Study)

Number of Participating States: 6

URL: www.pooledfund.org/projectdetails.asp?id=380&status=4

Funded by: SP&R/SRP

Total Cost: \$335,000 **MN Paid in 2009:** \$15,000

Performed by: Mike Anderson **PI:** Mike Anderson

TL: Tom Wood

AL: Bruce Holdhusen

Description: The purpose of this study is to determine the proper timing of preventive maintenance treatments to optimize life cycle costs and pavement performance. Researchers will seek to better understand the aging mechanism and how it can be reduced through pavement preservation. Work will be performed on newly built test sections at MnROAD.

Status: After developing and advertising a Request for Proposal, researchers selected a performing organization.

Start Date: 2007

Projected End Date: 2012

Work Complete: 10%



TPF-5(165): Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements

Number of Participating States: 6

URL: www.pooledfund.org/projectdetails.asp?id=389&status=4

Funded by: SP&R/SRP

Total Cost: \$360,000 **MN Paid in 2009:** \$0

Performed by: University of Pittsburgh

PI: Julie Vandebossche

TL: Tom Burnham **AL:** Nelson Cruz

Description: The primary purpose of this project is to create a unified national design guide for thin and ultrathin concrete overlays of existing asphalt pavements. In these guidelines, researchers will use existing validated performance models as well as new analytical models that address design aspects not currently considered in existing methods.

Status: The Task 1 report, a summary of existing projects and a literature review are complete. The Task 2 report on determining the best design model is near completion.

Start Date: 2007 **Projected End Date:** 2011

Work Complete: 25%

TPF-5(215): Transportation Engineering and Road Research Alliance

Number of Participating States: 5

URL: www.pooledfund.org/projectdetails.asp?id=443&status=4

Funded by: SP&R/SRP

Total Cost: \$120,000 **MN Paid in 2009:** \$5,000

Performed by: N/A. TERRA supervises and funds a number of different research projects.

TL: Maureen Jensen **AL:** Deb Fick

Description: The Transportation Engineering and Road Research Alliance was formed in 2004 by a task force of government, industry and academic representatives. TERRA's mission is to develop, sustain and communicate a comprehensive research program on pavement, materials and related transportation engineering challenges, including issues related to cold climates.

Status: Three new states have joined TERRA via the pooled fund. The board met in November 2009, and meeting dates for TERRA's standing committees were scheduled. Members continue to review the 28 project proposals received and plan for the third Innovation series event.

Start Date: 2009 **Projected End Date:** 2014

Work Complete: Ongoing

Congestion Management

TPF-5(171): Evaluation of Non-Intrusive Traffic Detection Technologies, Phase III

Number of Participating States: 13

URL: www.pooledfund.org/projectdetails.asp?id=398&status=4

Funded by: SP&R/SRP

Total Cost: \$225,000 **MN Paid in 2009:** \$0

Performed by: SRF Consulting Group **PI:** Erik Minge

TL: Jerry Kotzenmacher **AL:** Deb Fick

Description: The objective of this project is to conduct field tests of the latest generation of non-intrusive traffic sensors to assess the capabilities and limitations in detecting traffic under a variety of conditions. The needs of participating state agencies will determine specific test conditions.

Status: A kickoff meeting for the study was held in April

2009. The scope of work was defined, and a test site has been set up. Testing of five types of non-intrusive detection technology will begin shortly.

Start Date: 2007 **Projected End Date:** 2009

Work Complete: 40%

TPF-5(190): Northwest Passage, Phase III

Number of Participating States: 7

URL: www.pooledfund.org/projectdetails.asp?id=412&status=4

Funded by: SP&R/SRP

Total Cost: \$200,000 **MN Paid in 2009:** \$25,000

Performed by: Athey Creek Consultants **PI:** Dean Deeter

TL: Todd Kramasz **AL:** Deb Fick

Description: This series of projects will continue to integrate traveler information systems and coordinate maintenance operations across state borders along the I-90/I-94 corridor from Wisconsin to Washington.

Status: The team selected a contractor for a travel information Web site and for the center-to-center communications concept; issued a final report outlining the current status of 511 access to adjacent states' information; and selected a contractor to address a regional permitting system for commercial vehicles.

Start Date: 2008 **Projected End Date:** 2009

Work Complete: Ongoing

TPF-5(218): Clear Roads Winter Highway Operations Pooled Fund (continued from TPF-5(092))

Number of Participating States: 12

URL: www.pooledfund.org/projectdetails.asp?id=446&status=4

Funded by: SP&R/SRP

Total Cost: TBD **MN Paid in 2009:** \$275,000

Performed by: CTC & Associates LLC **PI:** Pat Casey

TL: Tom Peters **AL:** Deb Fick

Description: This project emphasizes state agency needs along with technology transfer and implementation in advancing national winter highway operations. Member states will evaluate new tools and practices in both lab and field settings, develop industry standards and performance measures, provide technology transfer and cost/benefit analysis, and support winter highway safety.

Status: Six research projects are currently in progress, with

two more to award soon. The Technical Advisory Committee met twice in 2009 and in January 2010 to review its budget, rate contractor proposals for the new projects, and discuss the results of the latest Product Experience Survey, where states weigh in on their experience with winter maintenance products. With the onset of 2010, Minnesota has become the lead state in this ongoing pooled fund effort.

Start Date: 2009 **Projected End Date:** 2011

Work Complete: 0% (as TPF-2(218))



Other Active Multi-state Pooled Fund Projects

Number of Participating States excludes FHWA but in some cases includes Canadian provinces.

Study Number	Title	Total Project Cost	Total MN Commitment	Mn 2009 Commitment	Number of Participating States	Lead State or Agency	Mn/DOT Contact	Start Date	End Date
SPR-2(207)	Transportation Management Center Pooled Fund Study	\$3,166,665	\$200,000	\$0	28	FHWA	Todd Kramasz	2000	Ongoing
SPR-3(017)/ TPF-5(193)	Midwest States Pooled Fund Crash Test Program	\$7,384,934	\$707,376	\$0	16	NE	Mike Elle	1991	Ongoing
SPR-3(020)	IVHS Study (ENTERPRISE)	\$1,170,000	\$120,000	\$30,000	9	IA	Ray Starr	1995	Ongoing
SPR-3(042)	Aurora Program	\$2,572,500	\$375,000	\$25,000	17	IA	Curt Pape	2003	Ongoing
SPR-3(049)	Urban Mobility Study	Over \$1,500,000	\$55,000	\$0	13	TX	Paul Czech	1997	Ongoing
TPF-5(004)	Long-Term Pavement Performance (LTPP) Specific Pavement Study (SPS) Traffic Data Collection	\$14,676,285	\$175,000	\$35,000	24	FHWA	George Cepress	2003	2009
TPF-5(029)	High Occupancy Vehicle	\$1,540,000	\$150,000	\$150,000	10	FHWA	Janelle Anderson	2002	2010
TPF-5(035)	Pacific Northwest Snowfighters	\$290,000	\$30,000	\$10,000	9	WA	Gabe Guevara	2007	2010
TPF-5(039)	Falling Weight Deflectometer (FWD)	\$1,875,700	\$55,000	\$0	12	FHWA	David Bullock	2004	2009
TPF-5(046)	Transportation Curriculum Coordination Council Training Management and Development	\$950,000	\$75,000	\$0	15	FHWA	Catherine Betts	2002	2013
TPF-5(054)	Maintenance Decision Support System (MDSS)	N/A	\$200,000	\$50,000	17	SD	Curt Pape	Ongoing	Ongoing
TPF-5(069)	Core Program Services for a Highway Research, Development, and Technology Program	\$17,500,000	\$127,705	\$0	20	FHWA	Sue Lodahl	2004	Ongoing
TPF-5(092)	Clear Roads (Test & Evaluation of Materials, Equipment & Methods for Winter Maintenance)	\$905,000	\$150,000	\$25,000	15	WI	Linda Taylor	2004	Ongoing
TPF-5(099)	Evaluation of Low Cost Safety Improvements	\$2,850,000	\$195,000	\$0	28	FHWA	Dave Engstrom	2005	2011
TPF-5(105)	Transportation Library Connectivity Pooled Fund	\$20,000	\$100,000	\$20,000	23	WI	Sheila Hatchell	2005	2009
TPF-5(109)	TRB Core Program Services	\$17,500,000	\$255,410	\$127,705	22	FHWA	Sue Lodahl	2007	Ongoing
TPF-5(114)	Roadside Safety Research Program	\$550,000	\$250,000	\$50,000	8	WA	Michelle Elle, Nancy Yoo	2005	2009



NCHRP Projects with Active Mn/DOT Panel Membership

Project Number	Project Title	Mn/DOT Panel Member	Role	Start Date	End Date
D0142	Models for Predicting Top-Down Cracking of Hot-Mix Asphalt Layers	Shongtao Dai	Member	2006	2009
D0146	Handbook for Pavement Design, Construction, and Management	Curt M. Turgeon	Member	2009	Pending
D0148	Incorporating Pavement Preservation into the MEPDG	Roger C. Olson	Member	Pending	Pending
D0362	Guidelines for Accessible Pedestrian Signals	Beverly Farraher	Member	2001	2010
D0391	Left-Turn Accommodations at Unsignalized Intersections	Brian K. Gage	Chair	2008	2010
D0836	Research for the AASHTO Standing Committee on Planning	Timothy A. Henkel	Member	1998	Ongoing
D0855	Developing a Logical Model for a Geo-Spatial Right-Of-Way Land Management System	Kevin F. Leonard	Member	2007	2010
D0860	Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Cost	Timothy A. Henkel	AASHTO Monitor	2007	2009
D0862	Transportation Performance Management Programs--Insight from Practitioners	Mark C. Larson	Chair	2007	2009
D0867	Integrating Individual Transportation System-Level Performance Programs to Determine Network Performance	Mark B. Nelson	Member	2008	2009
D0868	Citizen's Guide and Discipline-Specific Professionals' Guide for Context-Sensitive Solutions in Transportation	Scott D. Bradley	Member	2008	2010
D0870	Target-Setting Methods and Data Management to Support Performance-Based Resource Allocation by Transportation Agencies	Rabinder Bains	Member	2008	2010
D0871	Methodology for Estimating Life Expectancies of Highway Assets	Mark B. Nelson	Chair	2009	2011
D0875	Guidelines for Evaluation and Performance Measurement of Congestion Pricing Projects	Kenneth Buckeye	Member	2009	2010
D0879	Producing Transportation Data Products from the American Community Survey that Comply with Disclosure Rules	Jonette Kreideweis	Member	Pending	2010
D0930A	Calibration of Rutting Models for HMA Structural and Mix Design	Shongtao Dai	Member	2005	2010
D0940	Optimization of Tack Coat for HMA Placement	Roger C. Olson	Member	2005	2010
D0943	Mix Design Practices for Warm Mix Asphalt	Timothy R. Clyne	Member	2007	2010
D1071	Evaluation of CIP Reinforced Joints for Full-Depth Precast Concrete Bridge Decks	Daniel L. Dorgan	Chair	2006	2009
D1280	LRFD Minimum Flexural Reinforcement Requirements	Keith Molnau	Member	2008	2009
D1532	Context Sensitive Solutions: Quantification of the Benefits in Transportation	Scott D. Bradley	Member	2006	2009
D1533	Guide for Transportation Landscape and Environmental Design	Scott D. Bradley	AASHTO Monitor	2006	2009
D1539	Superelevation Criteria for Sharp Horizontal Curves on Steep Grades	James Allen Rosenow	Member	Pending	Pending
D1908	Costs of Alternative Revenue-Generation Systems	Norman S. Foster	Member	2009	2010
D202454G	2006 AASHTO Bottom Line Scoping	Jonette Kreideweis	Member	2007	2009

cont. ➔

NCHRP Projects with Active Mn/DOT Panel Membership, Cont.

Project Number	Project Title	Mn/DOT Panel Member	Role	Start Date	End Date
D2036	Highway Research and Technology – International Information Sharing	Mukhtar Thakur	Member	1993	Ongoing
D2059	Surface Transportation Security Research	Mark R. Wikelius	Member	2002	Ongoing
D2082	Next Generation Transportation Pooled Fund (TPF) Website	Susan J. Lodahl	Chair	2009	2012
D208307	Sustainable Transportation Systems and Sustainability as an Organizing Principle for Transportation Agencies	Robert Edstrom	Member	Pending	Pending
D2085	Renewable Energy Guide for Highway Maintenance Facilities	Robert Miller	Member	Pending	Pending
D2109	Intelligent Soil Compaction Systems	John A. Siekmeier	Member	2006	2009
D2431	LRFD Design Specifications for Shallow Foundations	Richard A. Lamb	Member	2007	2009
D2432	Scour at Wide Piers and Long Skewed Piers	Andrea Hendrickson	Member	2007	2009
D2433	Development of Design Methods for In-Stream Flow Control Structures	Petronella L. DeWall	Member	2008	2011
DF024	Preserving and Protecting Freight Infrastructure and Routes	William D. Gardner	Member	2009	2011

Active TCRP Projects with Mn/DOT Panel Membership

Project Number	Project Title	Mn/DOT Panel Member	Role	Start Date	End Date
TB34	Guidebook for Commingling ADA-Eligible and Other Passengers on ADA-Complementary Paratransit Services	Sarah B. Lenz	Member	2006	2009
TD13	A Guide for Implementing Bus-On-Shoulder (BOS) Systems	Jennifer Conover	Member	2006	2010

Active SHRP 2 Technical Expert Task Groups with Mn/DOT Membership

Project Number	Project Title	Mn/DOT Technical Expert Task Group Member	Role	Start Date	End Date
FB026	Guide for the Process of Managing Risk on Rapid Renewal Contracts	Jay Hietpas	Member	2007	2009
FB033	Preservation Approaches for High Traffic Volume Roadways	Roger C. Olson	Member	2008	2009
FB038	Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction	Bernard I. Izevbekhai	Member	2009	2011
FC013	Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes	Peggy A. Reichert	Member	Pending	Pending



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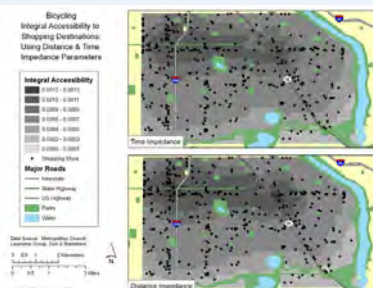
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Principal Investigators:

Kevin Krizek, University of Colorado
Robert Johns, University of Minnesota

PROJECT COST:

\$143,000



The project generated measurements showing accessibility to destinations by bicycle (above), walking and transit services.

Access to Destinations: Application of Accessibility Measures for Non-Auto Travel Modes

What Was the Need?

Accessibility, defined as the ease of reaching desirable destinations, is one of the measures that define transportation system performance. A greater understanding of how accessibility is changing would help Mn/DOT determine how well transportation and land use systems are working. Although transportation planners have been addressing accessibility since the 1950s, most planning efforts have focused on improving automobile mobility, and transportation research has tended to look at access to employment.

Broadening the scope of accessibility to include a variety of destination types and non-motorized modes of transportation—for example, walking and bicycling—has been much discussed but many feel inadequately addressed by planning initiatives and transportation research. One of the primary challenges in conducting research in this area has been the lack of reliable data and knowledge of non-motorized travel behavior that could be used to develop accessibility measures. Mn/DOT was interested in developing a methodology that could provide detailed accessibility measures for transit, walking and cycling that cover the entire seven-county Twin Cities metropolitan area.

What Was Our Goal?

The objective of this research—the final in a set of four Mn/DOT projects to address non-auto accessibility measures—was to develop accessibility performance measures for the Twin Cities metro area for three time periods (1995, 2000 and 2005) for transit, walking and cycling to see how accessibility has changed over that time. Researchers aimed to analyze travel data for these modes across a variety of corridor routes and correlated with local and regional patterns of land use. This information could then be used in planning transportation systems and optimizing land use policies.

What Did We Do?

Researchers used a measure of accessibility that forecasts the spatial distribution of trips; this is the same type of measure used in forecasting models for motorized vehicle travel. The model calculates accessibility at Zone A by measuring the activity opportunities in Zone B and applying a function to this that represents the travel time (time and distance were found equally effective as variables here), money and other costs involved in traveling from Zone A to Zone B.

Researchers used a variety of data sets to calculate accessibility measures for three modes (walking, cycling and transit) and several destination types (employment, retail, restaurant, school and recreation). A travel-related subset of metropolitan travel surveys provided travel behavior data. Public land use data and commercially available business inventory data were used to create the high-resolution land use data for the model.

To represent the finer-scale networks used for walking and cycling, researchers used data purchased from a commercial vendor that classifies businesses and used specialized software to match it with a parcel-level map of the region. The end result was a parcel-level geographic information systems layer that represents typical land uses at neighborhood and regional scales.

Time and distance, the final components of the model, were estimated using detailed data on trip distribution from a variety of sources, including transit on-board surveys and specialized trail use surveys.

continued

“Detailed and robust accessibility measures geared to non-motorized modes provide an additional option to form and evaluate land use transportation planning efforts.”

–Kevin Krizek,
Associate Professor,
University of Colorado
Department of Design
and Civil Engineering

“This study is the development of a scientific methodology to measure access for non-auto modes. Instead of measuring the number of vehicles a corridor can carry, we can start measuring the people-carrying capacity of a corridor.”

–Lisa Austin,
Mn/DOT Bicycle and
Pedestrian Planner

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This representation of an eight-block area of south Minneapolis is a sample of the parcel-level land use data researchers generated for use in the study’s travel forecasting model.

What Did We Learn?

To illustrate the procedures used to produce estimates of non-motorized accessibility, researchers calculated accessibility measures for a study area in south Minneapolis that contains approximately 1,600 block groups, with one block group equal to an eight-block area. Results of this test provided proof of concept: The extensive data set and procedures developed in the study resulted in detailed measures of accessibility for transit, bicycling and walking in this area.

Unlike previous research, this project introduced more behavioral realism into accessibility calculations by considering the time/cost factors going into travel choices and by employing highly detailed land use data. Researchers also improved on previous studies by applying calculations to relatively small units of analysis and constructing pedestrian and cycling networks that captured a fuller range of route choices than most travel mode networks include.

What’s Next?

The study’s accessibility measures can be used to inform the design of accessibility-related policies, identify where improvements in pedestrian infrastructure are warranted and assist in formulating land use transportation planning goals. Discussion will be required among Minnesota practitioners about how the findings of this study would best be put into practical use by planners at Mn/DOT and the Metropolitan Council.

This study is part of an ongoing effort to understand accessibility. More information about the methodologies, data and analysis procedures applied in this study can be found in three previous Mn/DOT research reports in the *Access to Destinations* series:

- [“Refining Methods for Calculating Non-Auto Travel Times”](#) (2007-24)
- [“How Close is Close Enough? Estimating Accurate Distance Decay Functions for Multiple Modes and Different Purposes”](#) (2008-11)
- [“Parcel Level Land Use Data Acquisition and Analysis for Measuring Non-Auto Accessibility”](#) (2008-19)

This Technical Summary pertains to Report 2009-24, “Access to Destinations: Application of Accessibility Measures for Non-Auto Travel Modes,” published July 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200924.pdf>.



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Michael Marti, SRF Consulting Group Inc.

PROJECT COST:

\$70,007



Case studies from 15 local agencies, with advice on implementing pavement management, are included in the resource guide.



RESEARCH
SERVICES SECTION

Putting Research into Practice: Implementing Pavement Management in Minnesota

What Was the Need?

Pavement management systems began to take shape in the late 1970s as state transportation agencies developed procedures to track pavement-related data and identify and plan pavement maintenance and reconstruction. In a typical example of today's commercially available PMS, information about specific stretches of road—such as pavement condition and characteristics; possible maintenance treatments; treatment cost; and historical construction, maintenance and rehabilitation data—is stored in a software program and used to generate budget analyses and reports.

Ideally, a PMS should provide a systematic approach to evaluate the present condition of each pavement surface, provide guidance for the type of maintenance that will keep the pavement at an acceptable level of service, prioritize necessary repairs and generate useful reports.

While some Minnesota cities and counties have successfully implemented a commercial-ly available or in-house PMS, other local agencies have yet to employ pavement management programs or may be failing to make optimum use of current systems.

What Was Our Goal?

The objective of this implementation project was to create an unbiased review of the capabilities, applications and benefits of PMS programs currently used by Minnesota agencies along with examples of innovative application of PMSs in Minnesota. This best practices guide would then help local agencies select an appropriate PMS, justify its purchase and operating costs, and allow current users of PMS tools to make more effective use of their existing programs.

What Did We Implement?

This project leveraged the efforts made by Minnesota's city and county engineers to administer pavement management programs. Knowledge derived from their experiences laid the groundwork for the development of educational tools that local transportation agencies throughout Minnesota can use to improve pavement management practices.

How Did We Do It?

First, investigators conducted a survey of Minnesota city and county engineers in the summer of 2008 to identify the PMS software programs in use. Local agencies were also asked to provide case studies that demonstrated their experience with commercial and in-house systems. Results of this initial survey were used to develop a second survey of the same group that asked respondents to evaluate commercial PMS features and functionality from a user perspective.

Results from the second survey were used to develop attributes for better understanding PMS software programs. Major categories of review criteria included cost, types of data inputs, availability of budget analyses, geographic information systems capabilities, data accessibility, support and ease of data input/output.

Investigators also administered the survey to PMS vendors based on these attributes to get the vendors' perspective of the features and functionality of their own products. Responses from the vendor survey were used to populate a matrix of system features of six commercially available PMS software programs used in Minnesota.

continued

“The case studies in the resource guide are a good source of information for prospective users who want to know more about implementing a pavement management system and its potential benefits.”

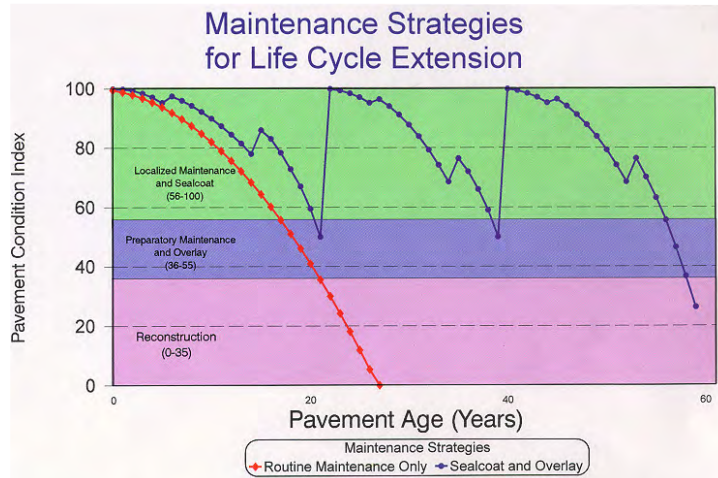
–Richard Sanders,
Polk County Engineer

“Within the resource guide is a matrix of pavement management systems that provides a side-by-side review of the software currently used in Minnesota. This, along with the case studies, packages a lot of Minnesota experience within one resource.”

–Michael Marti,
Principal, SRF Consulting Group Inc.

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The city of Eagan, Minnesota, has used pavement management since 1989, soon after the majority of Eagan’s pavements were constructed. This graph shows how Eagan’s PMS reflects the impact of different maintenance strategies on pavement condition.

What Was the Impact?

The resulting PMS educational toolbox provides:

- A resource guide that describes the PMS software programs currently used in Minnesota, including case studies that describe how local agencies are using commercially available and in-house PMS software programs to manage their pavement projects. The guide also includes a matrix offering side-by-side comparison of the features and functionality of several products including ICON (offered by GoodPointe Technology Inc.), MicroPAVER (American Public Works Association/U.S. Army Corps of Engineers), PASERWARE (the Wisconsin Transportation Information Center), PAVEMENTview PLUS (CartêGraph Systems, Inc.), PavePRO Manager (IMS Infrastructure Management Services) and RoadMatrix (Stantec Inc.). The report does not endorse any software or vendor; it simply provides a review of these products’ attributes.
- Curriculum and training materials for a PMS selection workshop developed for staff of local agencies considering acquisition of a PMS.
- A PMS brochure that can be used to educate county commissioners, city council members and members of the public about the use and benefits of a PMS.

What’s Next?

Three workshops were offered in fall 2009 to staff of Minnesota agencies considering acquisition of a PMS. In northern Minnesota, the PMS workshop was scheduled in conjunction with the Fall 2009 Mn/DOT District 2 meeting. A PMS workshop for staff in the Twin Cities metropolitan area was part of the preconference associated with the APWA Minnesota Chapter 2009 Fall Workshop and Conference. A third presentation is scheduled as part of the Spring Maintenance Expo in St. Cloud, Minnesota, in April 2010.

This Technical Summary pertains to the LRRB-produced Report 2009RIC11, “Implementation of Pavement Management in Minnesota,” published June 2009. The full report can be accessed at <http://www.lrrb.org/PDF/2009RIC11.pdf>.



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Adeel Lari, University of Minnesota

PROJECT COST:

\$65,000



Researchers analyzed property values in three counties to assess the appreciation rate of adjacent vacant properties.

Best Practices for Advanced Acquisition of Right of Way

What Was the Need?

For transportation projects such as roadway expansions, acquiring the land to build on—the right of way—can be one of the highest expenses. ROWs can be purchased at the time of construction (generally the most expensive option), or Mn/DOT can use various ROW preservation techniques including land-use regulation or negotiations with landowners. Advanced acquisition is the practice of obtaining land well in advance of when it will be needed for a transportation construction project. While this can save money, it can also result in reconveyance, whereby unused land is resold to property owners.

Some recent studies found little financial benefit from advanced acquisition, suggesting that further analysis is needed to ensure that Mn/DOT's current use of this practice is justified. Officials needed to know what circumstances warrant this practice; clearer guidelines for ROW preservation would simplify Mn/DOT's planning processes and save Minnesota money.

What Was Our Goal?

The objectives of this study were to:

- Assess current ROW acquisition practices in Minnesota.
- Investigate the appreciation of land adjacent to transportation corridors.
- Create a model to help project managers make decisions about advanced acquisition.

What Did We Do?

The study employed two surveys. Researchers first obtained information on ROW acquisition processes, including reconveyance rates, from eight Mn/DOT districts as well as Mn/DOT databases. Then they surveyed (typically via mail, but sometimes by phone) officials in 34 Minnesota cities and two counties on their use of ROW preservation tools and ways to improve the ROW acquisition process.

In the second part of the study, researchers selected three transportation corridors from around the state (based on property assessment data availability) to assess the appreciation rate of adjacent vacant properties. They compared groups of parcels located within 100 meters of these corridors to a control group of randomly selected properties from the three counties involved.

What Did We Learn?

A major survey finding was the lack of district-specific guidelines for the use of advanced acquisition and other ROW preservation tools. A majority of districts indicated that guidelines would help district staff make better use of these tools and encourage their consistent statewide application. This majority also asserted that greater use of official mapping—the practice of denoting where future roadways are planned in zoning maps—would result in more effective advanced acquisition, though this practice has been used relatively infrequently.

The Metro District was found to have a disproportionate number of reconveyances: While it accounts for 54 percent of statewide ROW expenditures since 1993, it is responsible for 68 percent of reconveyed parcels. This suggests that Mn/DOT's current acquisition practices could be improved.

continued

“The Minnesota Trunk Highway 36 case study indicates that tracking and purchasing properties with high potential appreciation, such as parcels that are about to subdivide or undergo land use changes, may help avoid higher ROW costs later.”

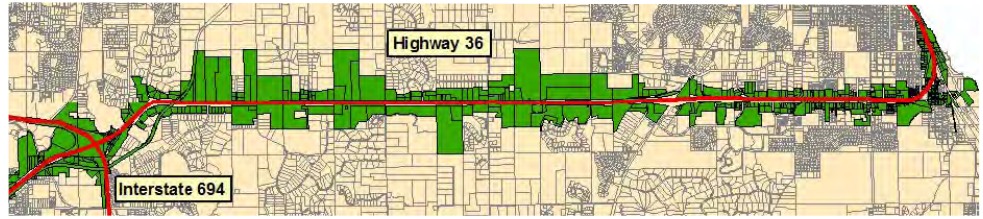
—Rabinder Bains,
Economic Policy Analyst,
Mn/DOT Office of
Investment Management

“This study identified the need for guidelines that can be applied by ROW engineers to determine how and when to use ROW preservation tools.”

—Adeel Lari,
Director, Innovative
Financing in the State
and Local Policy Program,
University of Minnesota
Hubert H. Humphrey
Institute of Public Affairs

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An analysis of 380 properties adjacent to Minnesota Trunk Highway 36 in Washington County revealed only a slight advantage in appreciation over those not adjacent: 9 percent in average growth compared to 7.9 percent. Nonetheless, the aggregate value of these properties was three times more than those in the control group in both 1996 and 2007.

The survey of Minnesota cities and counties highlighted the need for improved communication and coordination. Respondents who reported working with Mn/DOT on advanced acquisition noted a cooperative communication process but recommended initiating communication earlier in the roadway planning process to streamline ROW acquisition activities.

Initial findings from the land appreciation analysis were mixed. While researchers found that the average parcel adjacent to a transportation corridor is not a good candidate for advanced acquisition, they speculated that specific property characteristics could have predictive value in identifying categories of properties that appreciate rapidly and offer financial benefits with advanced acquisition.

Researchers tested this hypothesis with a finer-grained analysis of parcels adjacent to Minnesota Trunk Highway 36 in Washington County. The analysis showed that a property being subdivided increases the probability that the property will appreciate rapidly—more than 25 percent per year—by an absolute measure of 33.3 percentage points. This result suggests that Mn/DOT should focus its advanced acquisition activities on properties that are ready to subdivide or are subject to a land use change.

What's Next?

Researchers' recommended next steps include developing:

- Guidelines for use by Mn/DOT districts to increase awareness of ROW preservation tools. The new guidelines will augment the [Mn/DOT ROW](#) manual, which describes how to conduct advanced acquisition but does not provide guidance on when its use is recommended.
- A monitoring program for transportation corridors in the Twin Cities metropolitan area to identify properties that will be subject to subdivision or a land use change. Such a program can be used to identify candidate properties for advanced acquisition in areas where Mn/DOT is planning roadway expansion. Further study would help determine the usefulness of a monitoring program in other areas of the state.

This Technical Summary pertains to Report 2009-07, “Advanced Acquisition of Right of Way: Best Practices and Corridor Case Studies,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200907.pdf>.



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David Levinson, University of Minnesota

PROJECT COST:

\$51,832



The study reviewed reports from the 1980s or later for all major highways in the Twin Cities metro area.

Post-Construction Evaluation of Traffic Forecast Accuracy

What Was the Need?

When initiating a transportation project, engineers make use of traffic predictions to help ensure that the infrastructure developed will be neither larger than needed nor too small to meet future demands. The high costs and irreversibility involved in construction make it essential for these forecasts to be as accurate as possible.

Recent studies (such as [Flyvbjerg et al. 2003](#)) comparing pre-construction forecasts to post-construction traffic have found major inaccuracies in forecasting—overestimating demands and underestimating costs for large projects—that cannot be explained by random variation. Mn/DOT needed to understand the factors contributing to inaccuracies in order to minimize the risk of misspent funds. Advances in computing power that enable more widespread use of forecasting and make it easier to change Minnesota's forecasting data model make the time particularly right for progress in this area.

What Was Our Goal?

The objective of this project was to estimate the degree of accuracy of the roadway traffic forecasts used by Minnesota's transportation planners by comparing predicted traffic demands with actual traffic counts for several recently completed projects. Researchers aimed to analyze the reasons for any inaccuracies in these cases and to make recommendations for improving the accuracy of forecasts.

What Did We Do?

Researchers performed several analyses to estimate forecast accuracy on traffic data from Mn/DOT and the Twin Cities Metropolitan Council and traffic forecasts from various Mn/DOT reports prepared in support of roadway projects in the Twin Cities metro area; the metro area was chosen for ease of data availability. The data set included 108 project reports with forecasts covering 5,158 roadway segments; actual traffic information was obtained for 2,984 of these segments.

In addition, researchers interviewed seven individuals who were either originally involved in the travel demand forecasts for these projects or had used the data for various roadway projects; interviewees were asked about:

- Possible sources of inaccuracy in traffic forecasting
- What could have been done differently with the forecasting models used in the 1970s and 1980s given our current level of expertise
- How the Twin Cities forecasting model compares to other models
- Their responses to criticisms against traffic demand forecasting modeling
- Whether political pressure influenced forecast results

What Did We Learn?

Researchers confirmed a definite trend of underestimation in roadway forecast estimates, especially for higher volume roadways. Additional findings include the following:

- Underestimation increased as the number of years between the forecast year and the traffic report year increased.
- Forecasts made between 1970 and 1980 tend to overestimate as compared with those made between 1960 and 1970.

continued

“It was very worthwhile for us to evaluate the historical accuracy of post-construction roadway traffic forecasts. This is an area where there really haven’t been very many studies done.”

–Gene Hicks,
Mn/DOT Principal
Engineer

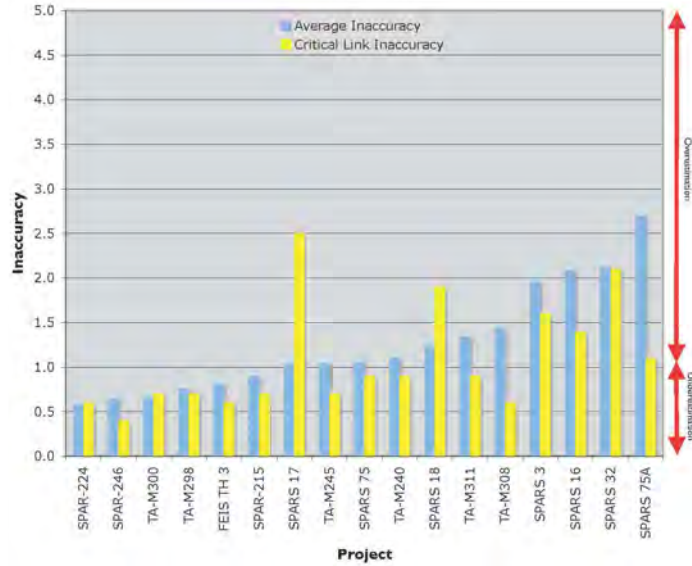
“This project included both quantitative analysis into the factors correlated with traffic forecast inaccuracy and qualitative analysis that helped identify the reasons for inaccuracy from a modeler’s perspective.”

–David Levinson,
Associate Professor,
University of Minnesota
Department of Civil
Engineering

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This graph shows the ratio of forecasted traffic to actual traffic for projects in Dakota County.

- Highways radiating from a common center were more prone to underestimation as compared with lateral highways.
- Forecasts for roadways running west from the Twin Cities showed a trend of underestimation, while those for roads running east were often overestimated.
- Several factors were difficult or impossible to anticipate, including new attractions (for example, the Mall of America), societal changes (such as increases in women in the workforce, the number of autos per household and use of the Internet) and world events (such as rising gas prices and the current financial crisis).

Interviewees for the most part agreed that political pressure was not a determining factor for inaccuracies in the Twin Cities projects; that the Twin Cities prediction model was as good, if not better, than those used by other cities; and that traffic demand predictions should not be based on the model’s results alone; rather the model’s data should be one tool used as part of the decision-making process.

What’s Next?

The project report recommends ongoing analysis of accuracy to continually refine modeling techniques, with better bookkeeping and archiving procedures to make it easier to conduct these types of analyses. In addition:

- Modelers must better understand the impact of societal changes on traffic forecasts and incorporate these rather than solely relying on existing trends.
- A greater emphasis on accurate demographics predictions will increase the likelihood of accuracy on traffic forecasts.
- Nonmodeler decision makers in charge of funding must obtain at least a basic understanding of the science behind forecasts, including the limitations and applicability of traffic forecasts.
- When making infrastructure decisions, a shift in thinking from using absolute numbers to using ranges would definitely improve the forecasting process.

This Technical Summary pertains to Report 2009-11, “Post-Construction Evaluation of Forecast Accuracy,” published February 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200911.pdf>.

The study referred to in the introduction is “Megaprojects and Risk: An Anatomy of Ambition,” by B. Flyvbjerg, N. Bruzelius and W. Rothengatter (2003).



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Michael Iacono, University of Minnesota
David Levinson, University of Minnesota

PROJECT COST:

\$72,637



This project analyzed residential sales trends near highway upgrades. This map shows 2000 to 2007 sales near US 52 in Rochester, Minnesota.

Impacts of Upgrading Roads on Local Property Values

What Was the Need?

Improvements to transportation networks tend to impact both users and local land markets. Past economic analyses of road improvements have focused primarily on benefits to users in the form of reduced travel costs and more efficient supply chains. The ability to quantify the benefits of road improvements through the examination of local property value impacts can provide a means for local governments to evaluate the merits of infrastructure investment and local road finance policies.

What Was Our Goal?

The objective of this study was to build on previous research related to local road finance policies and transportation costs to determine whether upgrading roads confers special benefits on adjacent properties of various types.

What Did We Do?

Researchers used case studies to evaluate the impact of highway improvements on property values. All case study candidates were in counties with transportation improvement projects that provided new capacity or added major new links to the road network, and each project had to have a total construction cost of more than \$10 million. Based on data availability, researchers selected three Minnesota counties for these case studies ranging from urban to rural with different types of recent, major construction: Hennepin, Olmsted and Jackson counties.

All three case studies used Mn/DOT construction logs and Minnesota Department of Revenue data on residential and commercial-industrial property sales transactions from 1999 (2000 in the case of Olmsted County) through 2007. The Hennepin County analysis also included data from the Multiple Listing Service, which provided a set of structural and locational attributes for analysis from 2001 through 2004, and regional parcel data to provide a land-use classification scheme for commercial-industrial property sales. Additional building characteristics derived from county records contributed to the Olmsted County analysis.

To estimate the effects of road network improvements on property values, researchers used statistical models (hedonic regression models) that decompose the value of a property into its constituent characteristics and estimate the implicit value of each characteristic. For case studies with a limited data set, researchers employed a more limited approach that split data into two time periods: before and after construction. For some properties, more robust data sets allowed researchers to estimate effects for specific years or for time periods before, during and after construction.

To gauge the impact of the highway, researchers designated an area of influence within one mile of the improved highway, segregated into contiguous quarter-mile buffer zones. Where residential properties were the focus of the analysis, researchers attempted to separate the effects of proximity to the highway itself from the effects of proximity to a highway access point.

What Did We Learn?

For most of the study areas and property types evaluated, no statistically significant change in property values was observed as a result of the construction or reconstruction project. The exception was the US 52 project in Olmsted County, where higher property values were observed for properties near the completed highway (within roughly one mile or less).

continued

“This study provides a strong foundation for continued and expanded investigation into the economic impacts of roadway upgrades in similarly composed areas of the state.”

—Ronald Lambert,
Mn/DOT Real Estate
Specialist Supervisor

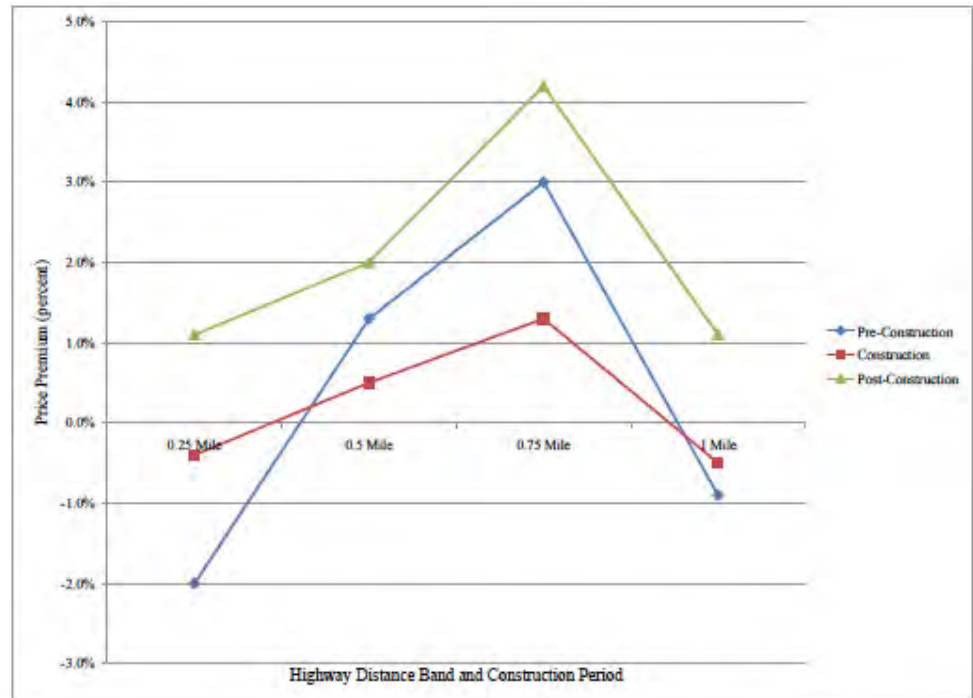
“Further research, using standardized methods and robust data sets, is needed to determine if the effects on land values identified in this study are consistent across locations of varying size and growth rates.”

—Michael Iacono,
Research Fellow,
University of Minnesota
Department of Civil
Engineering

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This chart shows the price effects of proximity of residential properties to upgraded US 52. Sale prices were higher during the post-construction period by 0.5 percent to 2.0 percent for properties within one mile of the upgraded highway.

Researchers found that for a number of construction projects in the study, it was difficult to make inferences due to small sample sizes, data sets with limited time periods and data sets lacking property attributes. Where sample sizes are limited—as was the case with most commercial and industrial property sales—there is a tradeoff between the level of detail of the analysis and the accuracy of the results. Researchers also noted that in most cases, the resulting improvements to transportation networks are not significant when, as in the case study locations, the highway network is largely developed.

What's Next?

The results of this study are being presented at regional conferences and seminars and at the 2010 Transportation Research Board Annual Meeting. The project outcome suggests the need for improved methods and data for analyzing the effects of transportation improvements on property values. Researchers propose two possible methods:

- Analysis of raw land sales rather than sales of land with structures reduces the need for extensive property attribute data like that found in MLS data and some county parcel records.
- With a repeat sales index method, trends in house prices or growth rates are analyzed over a given period using a set of properties that sell at least twice during the study period. This approach is best-suited to cases with smaller sample sizes and property-related data sets with limited structural and neighborhood attributes.

This Technical Summary pertains to Report 2009-16, “The Economic Impact of Upgrading Roads,” published June 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200916.pdf>.

Transportation Research Synthesis 0802, “Methods of Estimating the Economic Impact of Transportation Improvements,” which describes the researchers’ evaluation of possible methodological approaches to the study, can be accessed at <http://www.lrrb.org/PDF/TRS0802.pdf>.



RESEARCH SERVICES SECTION

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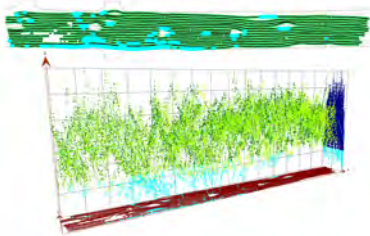
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Principal Investigator:

Lee Petersen, CNA Consulting Engineers

PROJECT COST:

\$84,457



Users can visualize data in a number of ways, including a 3-D trend analysis showing compaction value data points along and across the plane of compaction.

Managing Intelligent Compaction Data

What Was the Need?

To provide a strong and uniform foundation for a pavement, underlying layers must be compacted by rollers. Since 2005, Mn/DOT has completed [several demonstration, pilot and implementation projects](#) designed to improve the use of intelligent compaction. IC involves using sensors to measure the vibrations of rollers, which can be correlated to soil stiffness during the compaction process, allowing operators to make real-time adjustments. Rollers are also equipped with Global Positioning System technology to map the measures and time of compaction to its location, and store this data for future use in forensic analysis, long-term pavement management and mechanistic-empirical pavement design.

IC-equipped rollers produce very large quantities of data. Further, the software provided by roller manufacturers to manage this data is proprietary and expensive, may change and does not always include the capabilities desired by Mn/DOT. Previous pilot projects encountered problems using proprietary software for quality control and quality assurance; Mn/DOT required software customized to its needs.

What Was Our Goal?

The goal of this project was to develop software and processes for storing, processing and visualizing the large quantities of data produced by IC-equipped rollers so that it could be used for quality control and assurance.

Researchers originally intended this software for quality assurance use in the field, but complexities led to a revision of this goal to create an office tool for data analysis. Researchers aimed to develop software to convert data from the formats provided by roller manufacturers to a universal format that could be imported into a graphical information systems database.

What Did We Do?

Investigators began by developing database structures for storing IC data, including values related to the vibration of roller drums, such as frequency, amplitude and speed, stiffness measurements, and the time and location of each measurement. The databases also included tables for storing other material properties, and the general characteristics of equipment, such as drum size.

Investigators then developed software to import IC data into this database structure to identify data that was not collected at the specified operating settings and to export the data into a GIS format as a GIS shapefile—a condensed data file that contains the information essential to interpreting geographic information and spatial data within a geodatabase, in this case, to create a color-coded visualization of the quality of compaction by creating a map of the compaction area.

Finally, the team created a manual covering use of the software and processes for importing, converting, validating, visualizing and conducting a geostatistical analysis of data.

What Did We Learn?

Researchers produced a software package for handling the vast amounts of data produced by IC. This package is currently capable of handling data produced by Caterpillar equipment, and with further modifications, it would be capable of handling data from other manufacturers' equipment. This would eliminate the need for Mn/DOT to pay proprietary software fees that can run as much as \$40,000 per license.

continued

“This software gives us an excellent tool to review intelligent compaction data so that we can visualize uniformity and identify undercompacted areas, thereby improving the quality of compaction.”

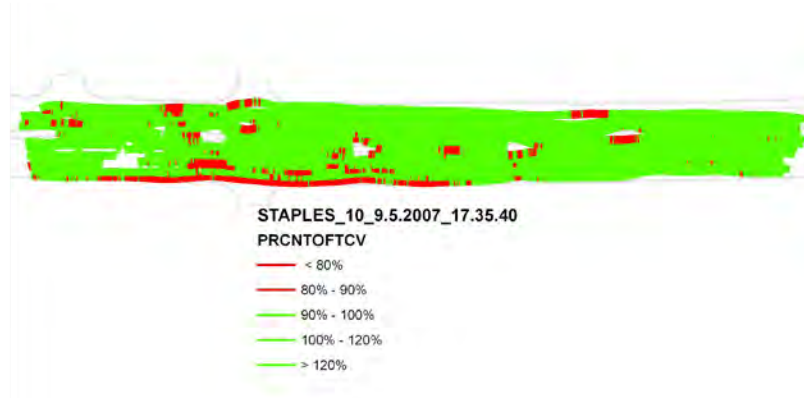
–**Rebecca Embacher**,
Mn/DOT Assistant
Grading and Base
Engineer

“Before this project, there was no standard output of IC data and no standard software to view it. We wanted a program developed in-house to use for any manufacturer’s data, without having to pay exorbitant licensing fees.”

–**Lee Petersen**,
CEO, CNA Consulting
Engineers

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After loading data into GIS software, users can view and analyze compaction value data as it compares to target compaction values via color-coded maps of the compaction area. In this case, compaction areas meeting or exceeding the target value of 80 percent are coded green, and areas not meeting it are coded red.

The software gives researchers a way to visualize and analyze compaction results, allowing the evaluation of compaction process, the uniformity of compaction across a pavement foundation, and the identification of weak and strong areas. The software can be used to direct field personnel where to conduct quality assurance testing using in situ measurement devices.

This software will also help Mn/DOT refine its specifications for contractors, such as acceptable variations in stiffness and in grade and layer thicknesses. It is applicable to both bound and unbound materials.

The final report includes a handbook describing the software’s target functionality, terminology, geodatabase structure and processes for filtering and importing data into geographic information system software.

What’s Next?

Researchers presented their results at the 2010 Transportation Research Board conference and will use this software to analyze data from recent MnROAD projects.

This project is part of a larger, ongoing Mn/DOT effort to implement IC technology. Information about both completed and active projects can be accessed at <http://www.dot.state.mn.us/materials/researchic.html>.

This Technical Summary pertains to Report 2009-35, “Mn/DOT Intelligent Compaction Implementation Plan: Procedures to Use and Manage IC Data in Real Time,” published December 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200935.pdf>.



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Principal Investigator:

Michael Marti, SRF Consulting Group Inc.

IMPLEMENTATION PROJECT COST:

\$25,565



The project produced an informational flier announcing and linking to the “Innovative Contracting Methods” report.



RESEARCH SERVICES SECTION

Putting Research into Practice: Innovative Contracting Resources for Local Governments

What Was the Need?

Mn/DOT, like many other state DOTs, has implemented some of the innovative contracting methods now approved for use by the Federal Highway Administration—design-build, A + B bidding, lane rental and warranties—to save time and money on transportation construction projects and reduce the time motorists spend in work zones.

While state agencies are taking advantage of new contracting methods, many local units of government lack the expertise to make effective use of these innovative practices on the transportation projects they manage. Other local agencies require assistance in developing good contracting practices using more traditional methods.

Local agencies seeking assistance with their contracting efforts can turn to Mn/DOT’s [Innovative Contracting Section](#) to find a wide range of resources that can help to reduce construction time and delivery of projects, improve quality and develop new processes to administer projects. Mn/DOT wanted to augment these resources with a how-to guide to help local governments use contracting processes more cost-effectively.

What Was Our Goal?

The objective of this project was to maximize the value of the resources available through Mn/DOT’s Innovative Contracting Section by providing a new resource to help local agencies improve their existing contracting processes and offer guidance in employing innovative contracting methods.

What Did We Implement?

The research being implemented through this project was informed by previous research sponsored by Mn/DOT and the Local Road Research Board:

- [“Performance Effectiveness of Design-build, Lane Rental, and A + B Contracting Techniques”](#) (2006-09), which presents 15 recommendations for improving management practices in the use of innovative contracting
- [“Best-Value Based on Performance”](#) (2008-40), which presents a contracting model based on an agency’s expected performance

How Did We Do It?

A technical advisory panel composed of representatives from local, state and federal agencies; contractors; and consultants was charged with identifying the contracting methods most appropriate for use on local projects in Minnesota. A May 2008 survey sought information about innovative contracting methods already in use by local agencies in Minnesota. Responses from 11 cities and 35 counties indicated the use of a wide range of innovative contracting practices, from A + B bidding to force accounts to warranties. Investigators conducted a literature search to identify the pros and cons of various contracting techniques and uncover details of the contracting methods the panel considered most suitable for use by local agencies. Finally, investigators queried experts within Minnesota and at the U.S. DOT about overcoming barriers to implementing innovative contracting practices.

continued

“Resources and assistance provided by Mn/DOT’s Innovative Contracting Section give local agencies greater freedom to act using alternate bidding, force account and other innovative contracting practices.”

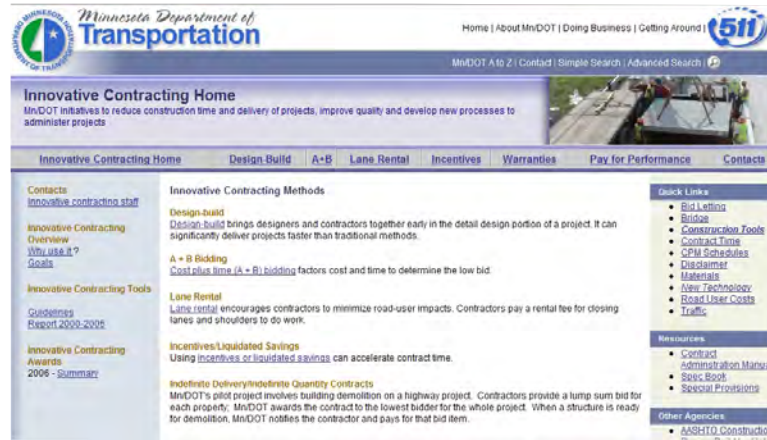
–Tom Behm,
District State Aid
Engineer/ADE, Mn/DOT
District 8

“While innovative contracting techniques are beneficial, often just focusing on the basics of traditional contracting methods can be equally effective for local governments.”

–Michael Marti,
Principal, SRF Consulting
Group Inc.

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Mn/DOT’s Innovative Contracting Web site (<http://www.dot.state.mn.us/const/tools/innovativecontract.html>) provides a wide range of resources to aid local agencies in implementing innovative contracting methods.

What Was the Impact?

The project report includes a step-by-step, question-and-answer format guide to improving the contracting process, including information to help local governments with more effective basic or traditional contracting. It also includes an overview of resources available through Mn/DOT’s Innovative Contracting Section and a list of local agencies that have experience with innovative contracting methods such as:

- **Best Value.** In 2007, the Minnesota Legislature passed a law that allows public agencies to select contractors based on best value rather than lowest bid. This contracting method can only be used with training and with approval by FHWA on a project-by-project basis *before* the project is advertised.
- **Alternate Bidding for Pavement Selection.** This practice permits a contractor to bid any designated alternate pavement design that is consistent with its expertise and equipment. The report provides links to resources, an outline of items to be addressed and a list of agencies with alternate bid experience.
- **Force Accounts.** This process allows Minnesota’s cities and counties to use State Aid funds when using local resources. Best used for projects composed of tasks typically conducted by maintenance staff, force account contracting allows for more flexibility to modify the scope of a project and can be cost-effective for smaller projects.
- **Bidder Qualification.** This competitive bidding process qualifies bidders based on a measure of acceptability defined by the agency and awards the contract to the lowest acceptable bidder. Local agencies are advised to use caution when using this method.

What’s Next?

In addition to reviewing the “[Innovative Contracting Methods](#)” report and making use of the resources available through [Mn/DOT’s Innovative Contracting Section](#), local agencies seeking assistance with their contracting practices can contact Mn/DOT’s District State Aid engineers or the [State Aid for Local Transportation office](#). Mn/DOT is developing workshops, expected to be available within the next year, that will provide the training required for agencies interested in using best value procurement.

This Technical Summary pertains to the LRRB-produced Report 2009RIC02, “Innovative Contracting Methods,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/2009RIC02.pdf>.

The research being implemented was informed by Report 2006-09, “Performance Effectiveness of Design-build, Lane Rental, and A + B Contracting Techniques,” published March 2006, and the LRRB-produced Report 2008-40, “Best-Value Based on Performance,” published September 2008. These reports can be accessed at <http://www.lrrb.org/pdf/200609.pdf> and <http://www.lrrb.org/pdf/200840.pdf>, respectively.



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PROJECT COST:

\$75,000



Dust control products could be sprayed by trucks used for applying asphalt products.



RESEARCH
SERVICES SECTION

Best Practices for Dust Control on Gravel Roads

What Was the Need?

Of the estimated 4 million miles of U.S. roads, nearly half are unpaved. Though the benefits of a paved road are numerous, the investment in converting a gravel road to a paved one is sizable, so most counties rely on maintaining their existing gravel roads.

One of the drawbacks of gravel roads is that they are prone to giving off dust, particularly as daily traffic increases. Clouds of road dust can be a nuisance for those living nearby as dust settles on their homes and parked vehicles. Road dust in the air can potentially affect the quality of life of nearby residents. This dust can also pose serious safety issues for drivers by causing impaired vision, especially on narrow roads or at intersections and railroad crossings.

What Was Our Goal?

The aim of this study was to evaluate the effectiveness of several common dust control products when applied to a variety of gravel surface roads at various schedules. The findings of this study would be used to better control the dust on rural roads and reduce the number of calls for service, particularly from residents moving to the country from the city who have higher expectations for dust-free roads.

What Did We Do?

Researchers selected 51 test sections—each either 0.5 or 1 mile—on roads in northwest, east-central and southwest Minnesota. Traffic levels varied from 25 to 700 vehicles per day, and gravel materials were mostly consistent across all roads.

Three dust control products were evaluated: calcium chloride, magnesium chloride and an organic polymer-plus-binder. Product was sprayed evenly onto the road from a tank truck. One treatment was applied during the first year, and dust levels were monitored throughout that year. In the second year, some roads were treated again while others were not. For comparison purposes, each road was also evaluated over sections having no dust control treatments during the two-year study.

A vehicle-mounted dust collector was selected to monitor dust levels because of its ease of operation, ruggedness and consistent field measurements. The collector was attached to the rear bumper of a Dodge 1500 pickup. While the vehicle traveled down the road at 40 mph, dust collected on a preweighed glass microfiber filter. Three sampling runs were performed on each test section; then the filter was sealed in a plastic bag and later weighed to determine how much dust was collected. Over the course of the two-year study, approximately 317 samples were collected from individual test sections.

Additionally, a field survey was sent out to all engineers who participated in the study to further aid in quantifying the performance, value and effectiveness of various dust control strategies.

What Did We Learn?

Overall, researchers observed that treatments lowered dust levels, which improved visibility, air quality and safety conditions on gravel roads.

- Results generally supported the assumption that higher application rates (more than once per year) reduce dust more effectively when applied to gravels containing greater amounts of fine aggregates (passing the #200 sieve). Treatments on gravel containing higher levels of sand, however, tended to be less effective.

continued

“It was extremely useful to be able to establish a best practice for dust control applications. I look forward to improving this practice with future research on emerging dust control products.”

—John McDonald,
Engineer, Faribault
County

“Gravel maintenance at railroad crossings can be a safety hazard. Chloride applications at these crossings would reduce maintenance requirements for these problem areas.”

—Eddie Johnson,
Research Project Engineer,
Mn/DOT Materials and Road Research

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This mobile dust collector, based on a device designed by Ado and Sanders called the Colorado State Dustometer, was built by the research staff.

- The surface moisture of roads was the best predictor of treatment effectiveness. Dust levels decreased with increased surface moisture. Treatments between 0.18 and 0.55 gallons applied per square yard appeared to maintain maximally effective surface moisture.
- A secondary benefit was observed in that treatments reduced the need for grading by a conservative estimate of 50 percent. Participants also perceived a reduction in the frequency of gravel replenishment.
- A single successful application of dust control product appears to last 100 to 150 days; the maximum time that a treated road will have noticeably less dust than an untreated area is 200 days.
- Magnesium chloride treatments were found to be as effective as those with calcium chloride; both were more effective than the organic polymer with binder.

What's Next?

Because of the resulting road surface stabilization from dust control applications, researchers recommend that spot treatment be considered for problematic intersections and railroad crossings where it is particularly difficult for maintenance trucks to reshape and replenish the gravel.

A growing number of agricultural and industrial byproducts show potential for being effective dust control agents. Also, a number of proprietary products have received formulation upgrades. Researching and documenting the performance of these products would be of great benefit for all agencies.

This Technical Summary pertains to the LRRB-produced Report 2009-04, “Best Practices for Dust Control on Aggregate Roads,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200904.pdf>.



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Magdy Abdelrahman, North Dakota State
University

PROJECT COST:

\$92,397



A triaxial pressure chamber was used to determine the resilient modulus of specimens by measuring their compaction under various loads.



RESEARCH
SERVICES SECTION

The Effect of RAP on the Structural Capacity of Pavement Base Layers

What Was the Need?

To reduce costs of construction and disposal of used pavement materials, Minnesota is increasingly recycling these materials when reconstructing highways. One of these materials, recycled asphalt pavement, is often used in the base course as a substitute for a portion of virgin aggregate.

However, unlike virgin aggregates, which are not bound together, RAP aggregates are coated with aged asphalt binder. Little research is available on whether moisture or freeze-thaw conditions affect the RAP binder in a way that causes the aggregate in the RAP to behave differently from typical unbound aggregates and how this might affect the structural capacities of base layers containing RAP.

What Was Our Goal?

The objective of this study was to evaluate the effect of freeze-thaw cycles and severe moisture conditions on the structural capacity of RAP base layers, where structural capacity is defined as the combination of stiffness—measured as resilient modulus—and shear strength.

What Did We Do?

Researchers began by conducting a literature review on the material properties, testing methodologies and nature of moisture damage for RAP in base materials. Then they compiled RAP material test results from Mn/DOT databases and collected pavement samples from several highways in Minnesota, including one source of 100 percent RAP, one of Minnesota Class 5 virgin aggregate, and three Class 7 mixtures of RAP and virgin aggregate being used as a base layer. The 100 percent RAP, taken from Minnesota Trunk Highway 10, was blended with virgin aggregate at 50 percent and 75 percent RAP content.

Researchers then evaluated these samples in the laboratory for:

- Gradation, or the coarseness of the aggregate, using dry sieve analysis; gradation is an important material property affecting the stability of the base layer
- Asphalt content, or the percentage of aggregate consisting of RAP, using an asphalt extraction apparatus
- Moisture density, using the standard Proctor test and the Superpave gyratory compactor
- Aggregate RAP resistance to abrasion and degradation, using the Micro-Deval test
- The structural capacity of RAP as compared to virgin aggregate, using the resilient modulus test and following the National Cooperative Highway Research Program 1-28A test protocol
- Objective dry density, by compacting resilient modulus samples in a gyratory compactor
- Shear strength, using the triaxial shear test for resilient modulus samples compacted at optimum moisture content and maximum dry density at two confining pressures
- The effect of freeze-thaw on the resilient modulus and the shear strength of RAP as compared to virgin aggregate, by subjecting one set of samples to two freeze-thaw cycles

continued

“This is the first time Minnesota has performed freeze-thaw laboratory tests on recycled bases containing RAP. These tests indicate that there is no decrease in resilient modulus or degradation over time.”

–Tim Andersen,
Grading and Base
Engineer, Mn/DOT
Office of Materials

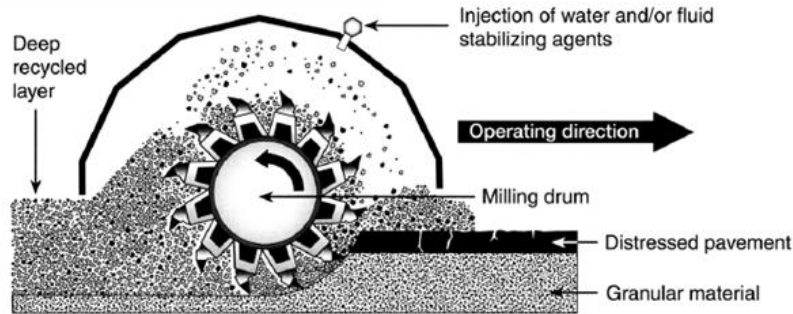
“This project clearly answered the question of how RAP affects the structure of base layers and shows that it is a viable alternative to virgin aggregate. The research will be useful not just to Minnesota but also nationally.”

–Magdy Abdelrahman,
Assistant Professor, North
Dakota State University
Department of Civil
Engineering

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A typical full depth reclamation involves ripping and breaking up the pavement and base with a reclaiming machine, saving construction costs and eliminating the issue of disposal.

What Did We Learn?

Researchers found that RAP had a higher resilient modulus and equivalent shear strength to Mn/DOT Class 5 virgin aggregate, and the effect of freeze-thaw cycles was negligible. While RAP gradation was coarser than virgin aggregate, it fell within Mn/DOT Class 5 gradation limits, and there was no clear difference in the friction angle and cohesion between RAP-aggregate blends, RAP-aggregate field samples and virgin aggregate.

Additional significant findings included:

- The maximum dry densities for RAP and RAP-aggregate blends were lower than for virgin aggregate, but there were conflicting measurements for moisture content. According to gyratory compactor testing at 50 gyrations, the optimum moisture content for RAP-aggregate blends was lower than for virgin aggregate, but according to the Proctor test the optimum moisture content for the RAP-aggregate blend was higher.
- Freeze-thaw of RAP-aggregate blends at low confining pressures reduced their shear strength, but this effect was unclear at higher confining pressures.
- The resilient modulus for all RAP material was higher than that of Class 5 aggregate. In general, the resilient modulus of RAP material was found to be dependent on confining pressure, and decreasing the moisture content increased the resilient modulus of RAP material.

What's Next?

Using RAP produced during pavement rehabilitation will reduce the amount of virgin aggregate needed, construction costs and lane closure times, as well as help agencies avoid the costs of disposing of used asphalt material recovered during pavement rehabilitation. The results of this research will help Mn/DOT to further evaluate the effectiveness of using RAP as a base layer. To determine whether there is additional degradation over time, researchers recommend further resilient modulus tests on field projects in five to 10 years. In the near future, researchers plan further evaluations of RAP in various road construction applications.

This Technical Summary pertains to the LRRB-produced Report 2009-05, “Investigation of Stripping in Minnesota Class 7 (RAP) and Full-Depth Reclamation Base Materials,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200905.pdf>.



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IMPLEMENTATION PROJECT COST:

\$292,385



An MEPDG software input screen for specifying asphalt layer thickness in inches.



RESEARCH
SERVICES SECTION

Putting Research into Practice: Calibrating the MEPDG for Minnesota

What Was the Need?

Traditionally, pavement design methods have been based on a limited amount of performance data acquired in the 1950s through road tests sponsored by the American Association of State Highway and Transportation Officials. As pavement materials and highway loads have changed, these methods have become less accurate for predicting the performance of a pavement over its design life.

To address this problem, AASHTO and the National Cooperative Highway Research Program developed the [Mechanistic-Empirical Pavement Design Guide](#) in 2002. This manual and accompanying software employ a design methodology grounded in engineering mechanics and validated with extensive road test performance data, providing engineers with distress models for predicting the structural and functional performance of various types of flexible and rigid pavements. By inputting traffic, climate and materials data, engineers can use these models to estimate how much damage will accumulate in a given pavement over a specified period of time. To be used accurately, however, these models must be calibrated to local conditions in every state.

What Was Our Goal?

The objective of this implementation effort was to calibrate the most current NCHRP mechanistic-empirical design procedure to conditions in Minnesota by:

- Developing guidelines for major input parameters, including traffic, material properties and subgrade characterization.
- Performing a comprehensive sensitivity analysis and identifying deficiencies in MEPDG software.
- Comparing its predictions to those of MnPAVE (Minnesota's mechanistic-empirical pavement design software) and Mn/DOT's current design standard.

What Did We Implement?

This project was an implementation of the Mechanistic-Empirical Pavement Design Guide. This undertaking was informed by recent Mn/DOT and Local Road Research Board efforts, including report [2008-23](#), "Effects of Seasonal Changes on Ride Quality at MnROAD," a project to update [MnPAVE](#) (LRRB INV 828), and other recent projects.

How Did We Do It?

For rigid pavements, investigators examined faulting, cracking and International Roughness Index models. For flexible pavements, they evaluated rutting, alligator cracking, transverse cracking and IRI models.

Investigators began by developing recommendations for the default Minnesota values of MEPDG inputs for both rigid and flexible pavements, including traffic information and material properties. These inputs were obtained using performance data from MnROAD concrete and asphalt pavement test sections, and materials test data from Mn/DOT databases.

Investigators then conducted a sensitivity analysis to evaluate how the performance predicted by distress models using these default inputs compared with expected predictions for Minnesota, as well as how dramatically the predicted performance changed in response to changes in design inputs.

Finally, investigators recalibrated MEPDG models to reduce the difference between predicted and measured performance.

continued

“We made significant progress in helping AASHTO debug its MEPDG software, which will increase the accuracy and usability of future versions.”

–Jerry Geib,
Mn/DOT Pavement
Design Engineer

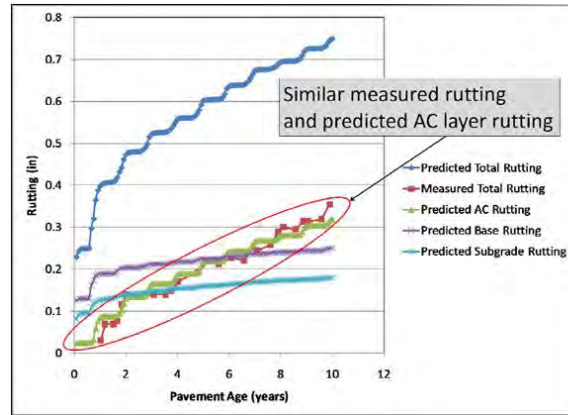
“Since the MEPDG won’t be deployable soon, Mn/DOT and LRRB are continuing to work on improved design methods and tools, especially for improved rehabilitation strategies such as overlays and reclamations.”

–Maureen Jensen,
Minnesota Road
Research Manager

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A comparison of the MEPDG models with MnROAD forensic studies showed that while these models are fairly accurate in predicting rutting in the asphalt layer, they significantly overestimate subgrade and base rutting.

What Was the Impact?

Investigators successfully recalibrated most models for Minnesota conditions, reducing the MEPDG bias and error in design predictions for both rigid and flexible pavements.

For rigid pavements, investigators found that MEPDG statistical analysis verified the trends observed in cracking and faulting charts, and recommend implementing the MEPDG for rigid pavements using the modified cracking model coefficients developed during recalibration. The most important parameters identified for control of the level of both cracking and faulting were traffic volume, slab thickness, base thickness and coefficient of thermal expansion.

Some parameters appeared to affect cracking and faulting differently. A change in the flexural strength of the concrete significantly affected the level of cracking, but did not cause a significant change in faulting. Dowel bar diameter dramatically affected the level of faulting, but did not affect the percentage of cracked slabs. Finally, the effect of supporting layer strength had an insignificant effect on both cracking and faulting.

For flexible pavements, investigators found numerous issues with MEPDG models, including inaccuracies and software problems related to MEPDG subgrade characterization, stabilized base characterization, asphalt binder characterization and climate inputs. While investigators recommend using the modified rutting model and the modified coefficients for the alligator cracking and thermal cracking models developed in this study, they do not recommend using the MEPDG longitudinal cracking and IRI predictions for flexible pavements.

What’s Next?

AASHTO is expected to sponsor a significant upgrade to the MEPDG software during the next several years; future work will be needed to validate this upgrade and recalibrate its distress models for Minnesota conditions. The current software version, with proposed model adjustments, should be used only for pilot evaluations of the MEPDG. It may be years before full implementation of the MEPDG can occur; Mn/DOT and LRRB are working to fully deploy the design tools and methods already available to local agencies.

This Technical Summary pertains to the LRRB-produced Report 2009-06, “Implementation of the MEPDG for New and Rehabilitated Pavement Structures for Design of Concrete and Asphalt Pavements in Minnesota,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200906.pdf>.

The research being implemented via this project is the 2002 Mechanistic-Empirical Pavement Design Guide, available at <http://www.trb.org/mepdg/guide.htm> (see <http://ntlsearch.bts.gov/tris/record/tris/01123422.html> for the 2008 MEPDG Manual of Practice). More information about Mn/DOT’s MEPDG efforts can be found at <http://www.dot.state.mn.us/materials/pvmtdesign/mepdg.html>.



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Principal Investigator:

John Nieber, University of Minnesota

PROJECT COST:

\$186,735



The handheld electromagnetic gauge is a promising tool for non-destructive testing of moisture levels in and beneath pavement layers.



RESEARCH
SERVICES SECTION

Evaluating Roadway Subsurface Drainage Practices

What Was the Need?

Effectively managing water in road systems is critical to the long-term effectiveness of highways. Few things challenge road structures the way moisture does. Water softens subgrades, erodes shoulders and contributes to pavement cracking and deterioration. Freeze-thaw cycles intensify the impact of moisture contained within the pavement structure.

Edge drains—systems that allow water to filter down through shoulder gravel into trenches and pipes that carry the water away—have long been a preferred method for managing subsurface drainage. Edge drains effectively manage runoff, the water shed by the roadway surface. These systems keep moisture from softening subgrades and reducing the structural strength of pavement. Effective drainage systems also keep water from gathering in lanes and challenging driver safety.

Water occasionally rises up from beneath a subgrade into the base and even into the bound pavement layers; edge drains offer little protection against this condition. Engineers have proposed centerline drains—systems that drain water from beneath the center of a road rather than from its edges—as an alternative to edge drains. If centerline drains can handle surface runoff, prevent water from gathering on lane surfaces and redirect water rising from beneath, then drainage systems would require only one line of drains in the center rather than lines at both edges. Such a system would save money spent on construction and materials as well as on maintenance.

What Was Our Goal?

This project aimed to determine if centerline drainage systems are an effective alternative to edge drains. By testing edge drains against centerline drains at various depths, investigators hoped to identify effective configurations of centerline drains.

What Did We Do?

Researchers tested drainage system configurations on an eight-mile stretch of highway in Nobles County. In 80 sections of 500 feet each, crews installed various combinations of edge drains at the shoulders, centerline drains at two-foot depths and centerline drains at depths of four feet beneath the pavement surface. On these highway segments, researchers gathered three kinds of data:

- To read drainage volume, they installed tipping buckets inside locked barrels fixed with instruments at drainage system outlets.
- To gather on-site moisture data for pavement, base and subgrade, researchers used a handheld electromagnetic gauge at each segment.
- To determine the extent to which material leaching through recycled concrete aggregate calcifies, obstructing the flow into the drain, they inspected select draining sections for calcification deposits.

The researchers also considered a fourth set of data: They collected electromagnetic induction instrument readings from four sections of roads with various drainage configurations in the city of Worthington, Minnesota.

What Did We Learn?

Investigators gathered data during a two-year period over 2006 and 2007, and found that:

continued

“The quantity of water that the edge drains redirected surprised me. It was significantly higher than the volume drained from centerline systems.”

—Stephen Schnieder,
Director, Nobles County
Public Works

“We essentially found that edge drain systems should remain the recommended design for roadway drainage. In cases in which the subgrade is permeable, deep centerline drains may be a good alternative.”

—John Nieber,
Professor, University of
Minnesota Department
of Bioproducts and Bio-
systems Engineering

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Researchers cut out sections of edge drain pipes to evaluate sediment composition.

- Edge drains redirected by far the greatest volume of water of the three configurations sampled, with no significant difference measured between volumes redirected by edge drains on one side of the roadway or the other.
- Data showed no significant difference in drainage volume between two-foot and four-foot centerline depths. Over impermeable subgrades, the four-foot depths redirected somewhat higher volumes.
- Electromagnetic gauge readings showed more moisture present within edge drain lines than within centerline drains, but less in pavement structures and bases with edge drains than with centerline drain sections.
- Drainage lines that showed high levels of carbonate deposits were not in sections with recycled concrete aggregates, an unexpected finding. Researchers believe the deposits may have come from carbonate sands in those locations.
- Data did not match expectations that the older roads in Worthington would show higher moisture levels than the newer roads. Instead, one of the new roads produced higher retained moisture in bases than the others. Researchers found a loose but not compelling correspondence between moisture readings and pavement distress on old and new roads.

Researchers concluded that edge drains should remain the recommended drainage system design for highways and urban roadways. In cases of permeable subgrade in areas in which water sources could force moisture up into a structure, centerline drainage may yet be useful. If centerline drainage systems are to be used, the deeper configuration should be favored.

Investigators also concluded that the height of a roadway surface with respect to surrounding ground was not a significant factor in drainage performance.

What's Next?

No changes to pavement standards were recommended as a result of this study. The specific electromagnetic gauge used in this study, the Geonics EM38, shows promise as an in situ, point-by-point, nondestructive device for measuring moisture in and underneath pavement structures. The EM38 could have applications in roadway evaluation and in assessments for retrofitting or other maintenance, and its use and calibration warrants further investigation.

This Technical Summary pertains to the LRRB-produced Report 2009-08, “Evaluating Roadway Sub-surface Drainage Practices,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200908.pdf>.



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PROJECT COST:

\$20,000



Introducing moisture into a stream of hot asphalt creates a foam that mixes well with aggregates.



RESEARCH
SERVICES SECTION

Recycled Pavements Using Foamed Asphalt in Minnesota

What Was the Need?

Foamed asphalt is formed by injecting small quantities of cold, atomized water under pressure into hot asphalt binder. On contact with the binder, the water becomes steam, producing an asphalt foam that is mixed with pulverized asphalt pavement materials at the job site. As the mix cools, the steam evaporates, leaving the binder-coated aggregate in place as a stabilized base course. Because its surface area is greater than that of regular liquid asphalt, foamed asphalt mixes more easily with recycled pavement materials.

Consequently, foamed asphalt is commonly used with cold-in-place recycling and full depth reclamation of asphalt pavements. These processes involve pulverizing, reprocessing and recompacting existing pavements at the end of their service life to create a new base course rather than completely removing the material. The benefits of foamed asphalt include lower binder and transportation costs, increased efficiency and decreased environmental impact. Foamed asphalt also adds strength and moisture resistance to reclaimed pavement materials.

Despite these benefits and the advances in technology that have led to the wide use of foamed asphalt in Europe and other parts of the world, its use is still relatively new to the United States. In those states where foamed asphalt has been used successfully, little performance data has been generated to guide pavement engineers and designers. In Minnesota, only two counties have used foamed asphalt cold-in-place recycling with success. Minnesota does not have a foamed asphalt specification or design guide, and there was a need for data on best practices to guide its use in the state.

What Was Our Goal?

The objective of this project was to gather and record information regarding best practices, construction techniques, mix design, specifications and performance of foamed asphalt recycled pavement. This information could then be used to develop design guidelines and specifications for using foamed asphalt in Minnesota.

What Did We Do?

Investigators began by conducting a literature search to find information about topics identified as most critical to successful completion of foamed asphalt reclamation. These topics were determined by meeting with experts and reviewing reports from past construction projects using foamed asphalt, and included mix design, subgrade soils, material properties of foamed asphalt, early life-cycle performance, project selection and general site conditions, and existing pavement structure and conditions.

Investigators then surveyed city and county transportation officials to find Minnesota counties that had used foamed asphalt for road rehabilitation. Of these, Fillmore and Olmsted counties both had used foamed asphalt with cold-in-place recycling to rehabilitate roads from 2004 to 2008.

Finally, investigators visited project sites in these counties and took on-site falling weight deflectometer measurements, where the pavement's reaction to a falling weight is measured. They performed laboratory analyses on asphalt cores extracted at these sites to examine the properties of the stabilized pavement layer as well as the material properties of the foamed asphalt.

What Did We Learn?

Field observations and surveys of city and county officials indicated that Minnesota foamed asphalt projects have been successful, providing a smooth, durable platform for

continued

“Foamed asphalt technology shows a lot of promise for rejuvenating existing investments in roadways, producing a brand-new driving surface with less cost than the conventional tear-them-up, throw-away, start-all-over approach.”

–Mark Maloney,
Public Works Director,
City of Shoreview

“This project is helping to generate the awareness in Minnesota that foamed asphalt is a safe and proven technology, and it gives engineers the information they need to begin using this technology.”

–Roger Olson,
Mn/DOT Research
Operations Engineer

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Foamed asphalt machines such as this one are used to pulverize the road surface and inject it with a foamed asphalt mixture that can be compacted on the roadway to form a new surface.

placing a surface treatment and apparently delaying the appearance of reflective cracking.

The falling weight deflectometer data analysis revealed that the recycled pavement layer developed a relatively uniform strength, despite the high variability inherent in most low-volume roads of the kind rehabilitated in these projects. Core data indicated that the foamed asphalt formed a cohesive matrix when mixed with the fines from the reclaimed material, which remained intact after coring.

Finally, by examining cold-in-place recycling and full depth reclamation specifications from the Iowa Department of Transportation, Nevada DOT and the Ontario Ministry of Transportation, investigators developed a preliminary specification for foamed asphalt applications in Minnesota. Special attention was paid to differences in gradation, binder grade, mix design and use of mineral stabilizing agents specified for cold-in-place recycling compared with full depth reclamation.

What's Next?

While this project developed a general preliminary specification for foamed asphalt applications in Minnesota, developing a complete specification will require more research and observation of actual construction to identify other factors and address potential issues or difficulties. Investigators recommend monitoring actual construction and performing falling weight deflectometer and ground-penetrating radar measurements along with core analysis before and after foamed asphalt projects. They also recommend continuing to monitor existing sites and collecting data throughout the lives of these pavements to properly examine their long-term performance.

One of the biggest obstacles to foamed asphalt use in Minnesota is lack of knowledge among engineers about its effectiveness and safety. Consequently, investigators will also be developing brochures about foamed asphalt and presenting the results of this study at upcoming conferences.

This Technical Summary pertains to the LRRB-produced Report 2009-09, “Recycled Pavements Using Foamed Asphalt in Minnesota,” published February 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200909.pdf>.



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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.



RESEARCH
SERVICES SECTION

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 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 observing construction at 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 because less time is spent kneeling near traffic at construction sites.

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, 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 induced by a 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, "[Validation of DCP and LWD Moisture Specifications for Granular Materials.](#)" 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, "[Moisture Effects on PVD and DCP Measurements.](#)" and Report 2007-11, "[Pavement Design Using Unsaturated Soil Technology.](#)"

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. An Olmsted County project was selected in which DCP and LWD measurements as well as traditional density testing were used to determine compaction quality.

continued

“These new tools dramatically reduce inspection time for determining the compaction of soils and subgrade applications.”

—Lawrence Berkland,
Assistant County
Engineer, Steele County
(Former Technical
Liaison)

“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 material type 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 compaction uniformity and higher productivity due to automation. In addition, use of these tests allows increased inspector presence at the construction site and improved inspector safety, and encourages more complete documentation and reporting.

These specifications covered the use of DCP and LWD for granular materials and fine-grained soils as well as target 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 Mn/DOT effort to implement intelligent compaction technology to ensure that Minnesota’s roads are constructed with the highest quality at the lowest cost possible. An assessment of these efforts was recently issued as [“Putting Research into Practice: Intelligent Compaction Implementation—Research Assessment”](#) (2008-22).

This Technical Summary pertains to the LRRB-funded report “Using the Dynamic Cone Penetrometer and Light Weight Deflectometer for Construction Quality Assurance,” published February 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200912.pdf>.

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.



RESEARCH SERVICES SECTION

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IMPLEMENTATION PROJECT COST:

\$425,000



LWDs determine stiffness by measuring the deflection of the ground induced by a dropped weight.

Putting Research into Practice: Intelligent Compaction Performance- Based Specifications in Minnesota

What Was the Need?

Before a road is paved, soils are compacted until they are stiff enough to provide a stable foundation for the pavement layers above them. Contractors typically determine the right amount of compaction effort to apply by measuring the in situ density or the ruts created by test rolling, or both. These techniques can be expensive and labor-intensive, and variability in soil properties makes it unreliable for achieving uniformly high-quality compaction over a large area.

Since 2004, Mn/DOT has completed [several demonstration and pilot projects](#) designed to improve this process using intelligent compaction. IC uses roller sensors to make real-time measurements of soil stiffness during compaction to optimize the compaction effort. IC is best used in combination with alternative spot-checking devices such as light weight deflectometers that provide a point of comparison to measurements of soil stiffness. LWDs can be used in situ, without requiring that samples be sent to a laboratory.

These past efforts still left several challenges to implementing IC. Protocols and target values for the use of LWDs required further development, and IC target values also needed to be improved through correlation with test rolling rut-depth measurements and mechanistic-empirical pavement design parameters. Finally, investigators needed to evaluate IC measurements for a wider range of materials, characterize them for spatial variability and improve IC data handling.

What Was Our Goal?

The overall goal of this research effort was to further IC implementation and determine mechanistic-empirical pavement design-based target values for IC and LWD use in construction quality control and quality assurance. Investigators also sought to evaluate factors affecting these correlations, including soil type, moisture content and in-ground stress levels. An additional goal was to educate and train Mn/DOT staff and contractors how to most effectively use IC and LWD technologies.

What Did We Implement?

This project leveraged past efforts to develop and evaluate IC technology, including these Mn/DOT reports:

- “Field Validation of Intelligent Compaction Monitoring Technology for Unbound Materials” (2007-10) (A [Technical Summary](#) is available.)
- “Intelligent Compaction and In-Situ Testing at Mn/DOT TH53” (2006-13)
- “Continuous Compaction Control MnROAD Demonstration” (2005-07)

How Did We Do It?

Investigators began by conducting field studies at four earthwork construction sites to document IC data, test roller rut depths, measurements from LWDs and other in situ measurements of granular and nongranular soils. Then they compared these values both to assess the variability of these measurement systems and establish correlations between their values.

Investigators then evaluated LWD error rates by comparing LWD measurements to laboratory analyses of compacted samples, and used this assessment to develop recom-

continued

“This project provided a vast amount of field data, and its analysis verifies the value of performance-based quality assurance. Implementation can be confidently accelerated with additional projects that will help Mn/DOT continue to refine its IC specifications.”

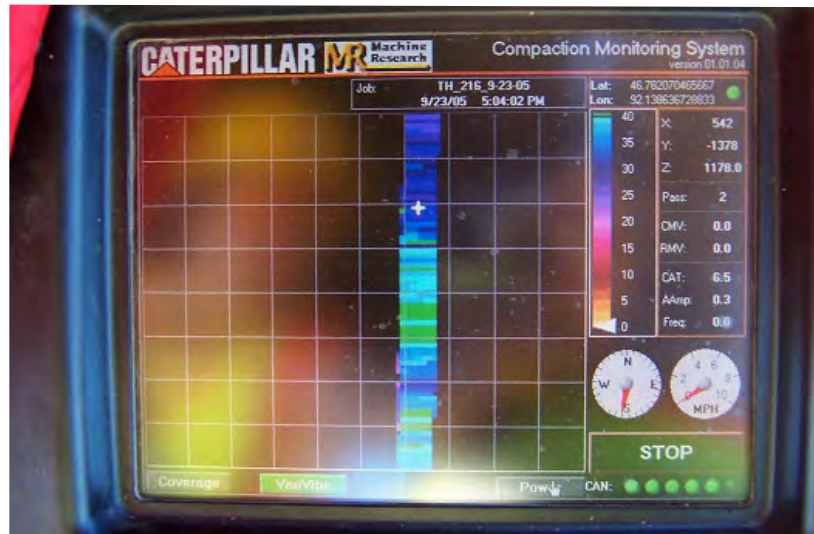
–John Siekmeier,
Mn/DOT Senior Research
Engineer

“This project demonstrated the potential for IC technologies to impact contractor process control and provide high-value data usable for both quality control and quality assurance with proper correlation.”

–David White,
Director, Earthworks
Engineering Research
Center, Iowa State
University

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IC rollers are equipped with a Global Positioning System to map the location, time and force of compaction. This data is stored for future use in forensic analysis, long-term pavement management and mechanistic-empirical pavement design.

mended IC and LWD specifications and testing protocols. Laboratory methods included soil index, compaction, strength and resilient modulus tests.

What Was the Impact?

Results showed that IC and in situ point measurements are alternatives to density testing and test rolling in many situations. Investigators calculated site-specific target values for IC, the LWD and shear strength. They also developed detailed empirical correlations between IC, the LWD and other in situ test devices such as dynamic cone penetrometers.

Investigators also developed four IC specification options: Three do not require on-site roller calibration, and one requires on-site calibration of IC and in situ point measurements. The latter option has the advantages of quantifying risk, establishing a framework for a performance specification and providing information for incentive-based pay.

Finally, early in the project investigators conducted five training seminars to give Mn/DOT staff and contractors information about and experience using IC and the LWD.

These results provided a framework for linking mechanistic-empirical pavement design to construction quality assurance and quality control.

What's Next?

This project is part of a larger, [ongoing Mn/DOT effort](#) to implement IC technology; an evaluation of some components of this effort was issued in Mn/DOT Report [2008-22](#), “[Intelligent Compaction Implementation: Research Assessment](#).” Minnesota is also a participant in a [multistate pooled fund effort to produce IC field demonstrations](#).

For future phases of this effort, investigators recommend establishing additional pilot projects and an IC training and certification program. Report 2009-35, “[Procedures to Use and Manage IC Data in Real Time](#),” will describe new software to make it easier to provide real-time data analysis during the construction process and to archive IC data for future use.

This Technical Summary pertains to Report 2009-14, “Implementation of Intelligent Compaction Performance Based Specifications in Minnesota,” published July 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200914.pdf>.

The three reports being implemented by this study as referenced above can be accessed at <http://www.lrrb.org/PDF/200710.pdf>, <http://www.lrrb.org/PDF/200613.pdf> and <http://www.lrrb.org/PDF/200507.pdf>. Information on current IC efforts is available at <http://www.dot.state.mn.us/materials/researchic.html>.



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Jim McGraw, Mn/DOT
Roger Olson, Mn/DOT

PROJECT COST:

\$30,789



Counties provided 6-inch-diameter wear and nonwear course core samples for the evaluation of dynamic modulus and other properties.



RESEARCH
SERVICES SECTION

Best Practices for RAP Use Based on Field Performance

What Was the Need?

Recycled asphalt pavement has been recovered from existing roads, crushed and filtered, and can be mixed with asphalt binders as part of a fresh hot-mix asphalt mixture. RAP is frequently used in many states—including Minnesota—in the base layer of asphalt pavements as a cost-effective and environmentally friendly way of building roads.

However, engineers have been wary of using RAP in the wear course, or top layer, of a pavement. Because the pavements from which RAP is reclaimed have already been subjected to harsh environmental conditions, including high temperatures and freeze-thaw, the behavior of asphalt pavements containing RAP is not as predictable as those without, and the pavements may be more prone to cracking and rutting. Because of these concerns, some Minnesota agencies using RAP exclude it from the wear course mixture.

What Was Our Goal?

The goal of this study was to determine whether asphalt pavements containing RAP in the wear course are prone to early failures.

What Did We Do?

Researchers first conducted a literature review and surveyed practicing local engineers from 52 Minnesota agencies to document the state's use of RAP in asphalt pavements. Survey questions focused on whether agencies used RAP in pavement design specifications, typical applications for which it was used and the effect of RAP on wear course performance. Researchers also asked about the percentages of RAP used for various applications, the most common performance grades of the asphalt binders with which it was mixed, and RAP recycling methods and stockpile management.

These survey results were used to select several construction projects for early performance monitoring. Selected projects included two bituminous overlay projects and four new pavement constructions reflecting current Minnesota practices and a range of field performance characteristics. After a period of service, researchers obtained wear course and nonwear course core samples from these sites and tested them for aggregate gradation, asphalt content and binder grade, specific gravity and dynamic modulus.

What Did We Learn?

Survey results showed that because of concerns about cracking, rutting and construction problems, roughly one-third of Minnesota agencies exclude RAP from wear course mixtures. Another survey result was that in Minnesota the most commonly used asphalt binders—in mixtures both with and without RAP—were performance grades PG 58-28 and PG 58-34. These typically included RAP at levels of 20 percent to 30 percent.

Field performance monitoring showed that PG 58-34 performed better than PG 58-28 during the early period of service of the selected construction projects. In one project, the use of 30 percent RAP with PG 58-28 binder led to extensive transverse cracking during the first winter of service, while in another the use of 20 percent RAP from the same source with PG 58-34 binder did not lead to early transverse cracks. While these pavements displayed popouts and spalling, another pair of projects using PG 58-34 binder with RAP from a contractor stockpile showed good performance during the first year, and only a few cracks in the RAP section during the second winter of service, suggesting that stockpile practices can affect performance.

continued

“Lab results showed that we can be less conservative about our use of RAP in the wear course, and that binder grade is more predictive of performance than the percentage of RAP.”

–Eddie Johnson,
Research Project
Engineer, Mn/DOT
Materials and Road
Research

“This study should ease any concerns counties may have had concerning the use of RAP in pavement wear courses.”

–John Brunkhorst,
County Engineer,
McLeod County

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Dynamic modulus tests were used to evaluate various RAP mixtures over a range of temperatures.

Lab test results showed that with the exception of one project, the asphalt binders met high- and low-temperature performance grade design standards. In general, wear and nonwear course mixtures performed essentially the same, and field performance depended more on the dynamic modulus of underlying layers, which significantly affected the performance of the wear course. Field performance also depended more on the low-temperature performance grade of new asphalt binder in the mixture than on its percentage of RAP.

What’s Next?

While survey results confirmed that many local engineers have concerns about using RAP in pavement wear courses, experimental results suggest that Minnesota agencies should consider revising their policies to allow RAP for this application. All RAP mixtures performed acceptably for rutting resistance, and results showed only a moderate relationship between the percentage of RAP in mixtures and the onset of early thermal cracking. Further, concerns about the low-temperature performance of pavements can be addressed during the mixture design phase by using low-temperature binders, whether or not the mixtures include RAP.

Researchers recommend using low-temperature performance grade -34 binders. They also recommend material control, including progressive RAP stockpile management techniques to increase recycling, attain high-quality designs and achieve optimum field performance. Stockpile management techniques include specifying the origin of source material, screening, and separating by particle size or asphalt content.

Further research is beginning using similar methods to analyze mixtures with higher RAP content and to determine best practices in the use of recycled shingles in hot-mix asphalt.

This Technical Summary pertains to the LRRB-produced Report 2009-15, “Best Practices for RAP Use Based on Field Performance,” published April 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200915.pdf>.



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PROJECT COST:

\$71,638



Rodent nests within the drainage pipe are one of the more common maintenance problems for subsurface drainage systems.



RESEARCH
SERVICES SECTION

Subsurface Drainage Manual for Minnesota Pavements

What Was the Need?

When water finds its way underneath roads, the roadway foundation will gradually weaken, causing the surface pavement to eventually fail. Avenues of entrance for water are numerous. For instance, water can infiltrate the surface or enter the foundation from the shoulder, or groundwater may rise up from below.

A [study conducted by the National Cooperative Highway Research Program](#) estimated that excess water reduces the service life of pavement systems by more than half. Although surface drainage practices will prevent some of this damage, subsurface drainage is required to fully address the problem.

An abundance of information is available to cities and counties for dealing with various highway problems, but there was not a single, definitive manual for addressing pavement subsurface drainage.

What Was Our Goal?

The objective of this project was to draw from existing literature and the expertise of practicing design engineers and highway managers to create a manual that would be specific to Minnesota conditions, taking into account the variability of the soils, hydrology and climate of the state.

This manual would be useful to all personnel involved in drainage needs assessment, design, construction, cost-benefit analysis and systems maintenance. The project also offered the hope of demonstrating the cost benefits of subsurface drainage so that practitioners would have an incentive to use the manual to assess their own drainage situations.

What Did We Do?

Investigators conducted a detailed literature review of all available research information and guides that have been assembled by federal highway agencies and industry associations. They compiled and augmented this information to create a design, construction and maintenance manual documenting best practices for pavement types and situations commonly found in Minnesota in six different areas:

- Methods for evaluating the need for subsurface drainage
- Selection of the type of drainage system to use
- Design of the drainage system
- Guidelines on how to construct and install subsurface drainage
- Proper maintenance of a drainage system
- Methods for conducting an economic analysis of subsurface drainage

Appendices to the guide provide recommended procedures, design plans, charts and tables, and additional examples.

What Did We Learn?

The manual identifies key factors determining the need for subsurface drainage, including traffic loads, climatic factors, pavement type and condition, subgrade characteristics, and design features such as pavement thickness and shoulder design. Consideration is also given to how much free water is permeating the pavement subbase and base layers,

continued

“This manual will be a good tool for engineers to reference when making decisions about subsurface drainage systems.”

–Dan Sauve,
Clearwater County
Engineer

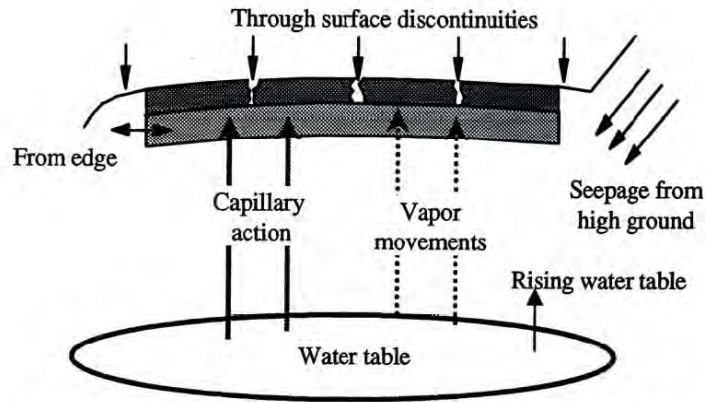
“We had the unique challenge of creating something that currently did not exist anywhere in the world. Initial feedback from engineers indicates that we have successfully done that.”

–Alan Rindels,
Mn/DOT Senior Engineer

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This diagram depicts avenues for moisture to reach the subsurface of a roadway. The main source of water infiltrating into pavement structural sections is from precipitation.

and determining whether this water is causing damage and whether it can be removed in a timely and cost-effective fashion.

Selecting a subsurface drainage system is in part determined by the type of pavement. Concrete pavements generally have lower permeability than asphalt pavements and will more effectively impede water infiltration into the subgrade layer. Data requirements for design and construction of drainage systems will vary depending on whether the system is a retrofit to an existing pavement, an installation for new pavement or a reconstruction.

Regular maintenance of pavement subsurface drainage systems is essential to the drainage system’s long-term success and, subsequently, to the life of the pavement. The manual addresses common maintenance problems such as vegetative growth around the drainage pipe outlets, rodent nests, mowing clippings and sediment collecting on rodent screens at pipe openings.

A number of studies reviewed for this project have reported on the cost-effectiveness of subsurface drainage. [One study](#) comparing cost and performance data found that the addition of drainage systems resulted in a minimum increase of four years of service life for asphalt pavements and a 50 percent increase in the life of concrete pavements. A general recommendation for the incorporation of subsurface drainage systems is that their total costs should never exceed 2 percent of the total installation costs of the pavement structure.

What’s Next?

This project created a manual that did not previously exist. Initial feedback from drainage engineers has been positive, and as more engineers and managers begin to use this manual to assess their own particular subsurface drainage needs, there will be opportunities to respond to their feedback by further tailoring the manual to their needs.

This project was carried out in conjunction with other efforts to refine subsurface drainage best practices; [LRRB Report 2009-08](#), “[Evaluating Roadway Subsurface Drainage Practices](#),” for example, evaluated the comparative value of centerline and conventional edge drain systems.

This Technical Summary pertains to the LRRB-produced Report 2009-17, “Subsurface Drainage Manual for Pavements in Minnesota,” published June 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200917.pdf>.



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Erland Lukanen, Mn/DOT

PROJECT COST:

\$42,493



Chip seals are typically applied to HMA pavements that are four to seven years old and can make these pavements look like new.



RESEARCH
SERVICES SECTION

Preventive Maintenance Best Practices for HMA Pavements

What Was the Need?

Pavements are currently deteriorating at such a rate that most agencies cannot afford to reconstruct them in a timely manner. As a consequence, many Minnesota agencies employ low-cost preventive maintenance techniques to extend pavement life: crack treatments such as rout and seal, clean and seal, and crack filling; and surface treatments such as thin overlays, chip seals, microsurfacing and fog seals. These treatments make asphalt pavements less prone to the effects of water and sunlight, which can harden and reduce the effectiveness of the pavement binder, leaving the pavement brittle. This can lead to cracking, raveling or the creation of rough patches on the pavement surface. Surface damage in turn allows water to penetrate the pavement's lower layers, causing them to soften and so reducing their ability to support the surface layers.

While maintenance treatments may help prevent or postpone these problems, such treatments are difficult to implement successfully over an entire network and must be applied at the right time to be effective. Implementation is further complicated by the improvement of bituminous aggregate selection, mix design, and quality control and assurance through [Superpave](#), the result of the asphalt research portion of the Strategic Highway Research Program.

What Was Our Goal?

The objectives of this study were to:

- Determine whether or not recent advances in bituminous mixtures and binder selection through Superpave necessitated a re-examination of current pavement management practices.
- Create a manual that provides Minnesota's city and county engineers with guidance on the use of preventive maintenance treatments as part of a long-term strategy for preserving and improving the condition of road networks.

What Did We Do?

Researchers first analyzed the effectiveness of pavement management treatments by modeling the decay of pavements over time using Mn/DOT historical pavement management data. This data has been collected since the 1960s during Mn/DOT's annual inspection of pavements using specially equipped vans that measure pavement roughness and rutting. Mn/DOT also routinely produces ratings of surface conditions using digital images of surface defects such as cracks and ruts collected every year. Taken together, this data is used to establish a surface rating that quantifies pavement condition and performance.

Next, researchers compared the surface ratings of roads that received preventive maintenance treatments to ratings for those that did not, taking into account the type of sealant used and the condition and age of the road to which the treatment was applied. Then they attempted to analyze this data to show how long various preventive maintenance measures extended the lives of pavements and whether applying treatments earlier in the lives of pavements was less costly than full rehabilitation later. These results and a literature search were used to create recommendations regarding available treatments and associated best practices for effectively applying them, detailing which treatments are best for which pavement conditions, when in the life of the pavement they should be applied and how often they should be applied.

continued

“This project is a good beginning to quantifying the benefits of treatments for preventive maintenance; a follow-up project will focus on control sections and enhanced measurement techniques.”

–Tom Wood,
Mn/DOT Research
Project Supervisor

“Continued study of how preventive maintenance affects the performance of various types of pavements is necessary to clearly identify the benefits and opportunities for improvement.”

–Erland Lukanen,
Mn/DOT Pavement
Preservation Engineer

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This project provided guidance on maintenance techniques like chip sealing as part of a long-term strategy to manage pavements.

What Did We Learn?

Changes in paving materials and methods over the last decade make it difficult to establish specifically at this point the degree to which current pavement management techniques extend pavement life and consequently provide cost savings. However, the literature review indicated that preventive maintenance treatments generally extend the lives of pavements. While Superpave improvements have eliminated rutting and delayed or reduced the rate of cracking, they do not adequately address long-term hardening caused by binder oxidation or increased moisture sensitivity with aging. Superpave pavements still require preventive maintenance.

These results formed the basis for a user manual for pavement preservation methods. This manual contains descriptions and definitions of the various available treatments as well as recommendations for the timing, type and application of treatments based on a pavement’s age and surface condition. In general, the best time for preventive maintenance is any time before the condition of the pavement deteriorates to a point at which it must be rehabilitated or reconstructed. Cracks should be sealed as soon as transverse cracks form and surface treatments applied earlier in a pavement’s life than is typical, when the surface still seems to be in relatively good condition.

Because such early preventive maintenance procedures are difficult to justify when pavements are in relatively good condition and other pavements in poorer conditions need attention, researchers recommend that the pavement preservation strategy include the appointment of a champion who advances the public’s understanding, secures funding and ensures long-term agency commitment.

What’s Next?

A subsequent Local Road Research Board study by the primary investigator of this study has been approved (“Cost-Effective Pavement Preservation Solutions for the Real World,” 2009-008: INV 886) to create a decision support system and training to provide city and county engineers with guidance in selecting among pavement maintenance options.

The report for the current project also recommends further research into the causes of nonload-related pavement cracking, the effects of deicing chemicals on hot-mix asphalt, and the effects of treatments on pavement safety and noise reduction.

This Technical Summary pertains to the LRRB-produced Report 2009-18, “Preventive Maintenance Best Management Practices of Hot Mix Asphalt Pavements,” published May 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200918.pdf>. Please contact research.dot@state.mn.us for more information on the follow-up research mentioned.



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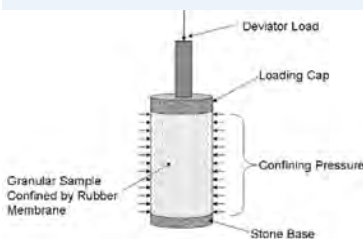
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Principal Investigator:

Kimberly Hill, University of Minnesota

PROJECT COST:

\$105,000



In the resilient modulus test, a cylindrical chamber is filled with a granular material and then subjected to pressure and stress.



RESEARCH
SERVICES SECTION

Mechanistic Modeling of Tests of Unbound Granular Materials

What Was the Need?

For a pavement to perform well, it is crucial that its base layer be well-designed. This layer is commonly composed of unbound aggregates, and designing this layer involves choosing aggregate grades and taking into account the thickness to which the layer will be compacted by machine rollers. Historically, design guidelines for aggregate layers have been based largely on past experience rather than mechanistic principles.

Recently, however, there has been an effort to use the American Association of State Highway and Transportation Officials Mechanistic-Empirical Pavement Design Guide to apply mechanistic principles to pavement design. Applying these principles requires evaluating existing tests used to measure the stiffness and strength of base layers composed of unbound aggregates. These tests include the California bearing ratio and resilient modulus laboratory tests as well as the dynamic cone penetrometer test for quality control in the field.

While there are a number of empirical correlations among the results of these tests, they are limited to the specific conditions under which the tests were performed. It would be helpful to have a more general, reliable, repeatable and well-defined mechanistic method for correlating test results. To develop this method, it would also be helpful to have a three-dimensional computer model that provides a detailed analysis of the mechanics of unbound materials. Specifically, the model should show how individual particles composing the aggregate interact with each other when subjected to different kinds of stresses, including how they resist deformation caused by uniform pressure and how they deform under different shearing stresses.

What Was Our Goal?

The objective of this study was to develop a mathematical model that provides a physics-based, mechanistic correlation between the California bearing ratio, resilient modulus and dynamic cone penetrometer tests. To accomplish this, researchers investigated and modeled relationships between the basic material properties of unbound aggregates, including the interaction of individual particles.

What Did We Do?

Researchers began by modifying existing computer code to model these three tests commonly used to characterize the granular materials that compose base layers. For the original code they chose software capable of creating 3-D models of detailed interactions between the individual particles in a granular material. This code, the 3-D discrete element model, or DEM, would allow researchers to investigate the effect of the basic physical properties of these particles on granular material test results.

Researchers modified this code by setting parameters for particles and algorithms for the simulation of their interaction. This preliminary model was then calibrated with existing laboratory and field data to enable it to better simulate real results. Finally, researchers further modified the model to determine mechanistic relationships between its results and particle properties.

What Did We Learn?

The calibrated DEM model achieved strong agreement between the results of the simulations and sample numerical and experimental studies on granular materials, and was shown to be capable of determining the effects on these tests of aggregate shape,

continued

“This study is a good beginning to developing a model that will give engineers better information on the ability of base layers to withstand loads so that we can properly design roads with longer life spans.”

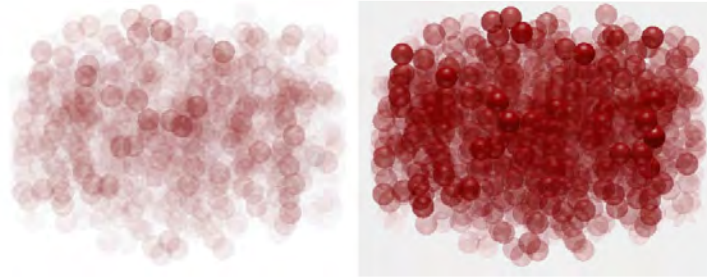
–Lee Amundson,
Lincoln County Engineer

“We found that the dynamic cone penetrometer and resilient modulus tests may to some extent be measuring different things. The relationship between these tests will consist not of a single equation but of various correlations for different types of materials.”

–Kimberly Hill,
Assistant Professor,
University of Minnesota
Department of Civil
Engineering

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Color intensity is used to indicate the relative magnitude of interparticle force distributions for the resilient modulus test during the rest period (left) and during maximum deviator stress (right).

coefficient of friction, gradation, stiffness and other properties as well as the statistics of interaction between particles.

Using this model, researchers found that the penetration depth of the dynamic cone penetrometer test is highly affected by the shapes of the particles, while the resilient modulus test is affected by the stiffness of particles and level of applied stress. The model also showed that the interaction between particles in granular materials varies significantly for different loading conditions.

Overall, the code shows promise for the development of mechanistic-based correlations between common granular materials test results as well as a more comprehensive mechanistic understanding of these test results.

What's Next?

While the model described in this report serves as a strong foundation for future research, more work is needed to fully develop a mechanistic model for tests of unbound materials. Researchers need computers with more power than is currently available to perform computations on the larger sample sizes necessary to fully develop this model. One possible solution to this problem is to develop more efficient DEM code capable of parallel processing between multiple computers.

More research is also needed to quantify different particle shapes and their effect on the characteristics of granular materials as well as the effect of specimen preparation techniques and other initial conditions.

Finally, because the current model assumes that aggregates are dry, researchers are planning a second phase of this study that takes into account the presence of moisture, mud and small particles such as sand; these factors can significantly affect the behavior of aggregates.

This Technical Summary pertains to the LRRB-produced Report 2009-21, “Mechanistic Modeling of Unbound Granular Materials,” published June 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200921.pdf>. For more information on Mn/DOT's implementation of mechanistic-empirical pavement design, please see <http://www.dot.state.mn.us/materials/pvmt/design/mepdg.html>.



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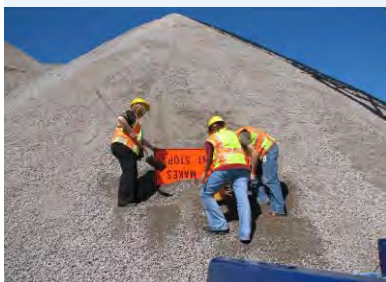
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Principal Investigator:

Satish Gupta, University of Minnesota

PROJECT COST:

\$155,225



Researchers collected recycled concrete from a stockpile managed by the city of Minneapolis.



RESEARCH
SERVICES SECTION

Strength and Drainage in Aggregates Mixed with Recycled Materials

What Was the Need?

The performance of pavements depends critically on the stiffness and strength of the foundation that supports them. The base and subbase layers of this foundation are constructed using large volumes of aggregates such as crushed stone, gravel and sand. Because of the high cost of purchasing and transporting aggregate, Minnesota transportation agencies are interested in replacing a portion of it with recycled construction and industrial materials when constructing new pavements. These materials include asphalt shingle, fly ash, municipal solid waste bottom ash, shredded tires, and concrete or asphalt reclaimed during the reconstruction of existing pavements. Using these materials also benefits the environment by enabling productive use of materials that might otherwise be sent to landfills.

However, there is limited information about how the addition of recycled materials to aggregates affects their mechanical, hydraulic and environmental properties. Mechanical properties include strength and stiffness, which are important for preventing pavement rutting and cracking. Hydraulic properties measure how materials retain or drain water; it is important that pavements drain well to avoid heaving during winter. Environmental properties are measured to assess whether materials leach inorganic chemicals—such as heavy metals—into the groundwater in concentrations higher than allowed levels.

What Was Our Goal?

The goal of this study was to compare the suitability of four recycled materials to that of virgin aggregates for use in the construction of road base and subbase layers. These materials included reclaimed asphalt pavement, reclaimed concrete material, fly ash and foundry sand.

What Did We Do?

Researchers began by collecting recycled materials from various locations in Minnesota. Then they mixed these materials in various proportions and combinations with virgin aggregate, creating 17 samples. They evaluated the hydraulic, mechanical and environmental properties of these samples as well as one sample of 100 percent virgin aggregate by measuring:

- Particle size distribution by repeatedly sieving samples and then calculating the ratio of the remaining to original material.
- Optimum water content corresponding to maximum dry density by packing moist samples at various water contents in a gyratory compactor.
- Water retention—a measure of the pore size distribution—by desaturating the compacted specimens in pressure plate chambers and measuring the amount of water retained in the specimens under various conditions.
- Hydraulic conductivity—the rate at which water flows through a material—measured at both the point of saturation and a little lower than this during the leaching test.
- Resilient modulus—a measure of material stiffness—by applying cycles of axial stress to cylindrical specimens in a triaxial cell at and slightly below its optimum water content.
- Shear strength—a measure of material cohesion—by applying a small contact load to a specimen and increasing it until the specimen fails to support it.
- Leaching characteristics, or the likely concentrations of heavy metals and other in-

continued

“Using recycled materials in road construction will not only produce substantial cost savings, but will also allow us to save energy and employ sustainable construction processes.”

–**Satish Gupta**,
Professor, University of Minnesota Department of Soil, Water, and Climate

“This report builds on the conclusions of previous studies that show that recycled materials can be used very effectively to produce durable roads when appropriate due diligence is conducted, including screening the source of waste and conducting the appropriate environmental testing.”

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

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To evaluate hydraulic, mechanical and leaching characteristics, researchers used a gyratory compactor to prepare specimens at maximum density, which more realistically approximates real-world pavements than specimens prepared using more common methods.

organic chemicals expected to leach from recycled materials into the groundwater, using laboratory tests that simulate this action.

What Did We Learn?

With the exception of foundry sand, recycled material mixtures were similar to virgin aggregates in drainage characteristics, stiffness, strength and environmental impact, and so are expected to be good substitutes for them as base and subbase materials in road construction.

Except for some RAP-aggregate mixtures with slightly higher fine contents, the particle size distribution of recycled materials was similar to that of virgin aggregates, and their hydraulic conductivities were higher, suggesting equal or better water retention and drainage. With the exception of foundry sand, the addition of recycled materials to aggregates increased their resilient modulus, and fly ash also improved their shear strength.

Environmental testing did not demonstrate that adding RAP, RCM and fly ash to virgin aggregates will lead to substantial leaching of toxic chemicals into the surrounding environment. With some exceptions, heavy metal concentrations in the leachate were generally less than those allowed by EPA drinking water standards. For some RCM mixtures and all fly ash mixtures, the leachate concentrations of some heavy metals were higher than allowed, but these concentrations are expected to fall below U.S. Environmental Protection Agency limits before reaching the groundwater by filtering through soils below the road foundation layers.

What's Next?

This project is part of an ongoing effort to determine the design, performance and economic characteristics of materials used in unbound pavement layers. The quantification of these characteristics is critical to the eventual movement by Minnesota's pavement designers to mechanistic-empirical pavement design.

This Technical Summary pertains to the LRRB-produced Report 2009-32, “Hydraulic and Mechanical Properties of Recycled Materials,” published October 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200932.pdf>.



RESEARCH SERVICES SECTION

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PROJECT COST:

\$49,350



This controller is an example of those used at Mn/DOT's WIM sites.

Development of Data Warehouse and Applications for Continuous Vehicle Class and Weigh-in-Motion Data

What Was the Need?

Mn/DOT's Office of Transportation Data and Analysis collects, manages and analyzes traffic data from a variety of sources, including 29 continuous vehicle classification sites and 12 weigh-in-motion sites that provide 24-hour traffic information. Mn/DOT uses VC and WIM data for pavement design and commercial vehicle weight enforcement. Monthly Traffic Monitoring Guide submissions to the Federal Highway Administration and traffic forecasting also use this data.

VC data can contain a number of possible combinations of volume (hourly), speed (the number of vehicles within specific speed ranges) and vehicle classification (the number of vehicles of each FHWA-defined type at each hour). WIM data are recorded as a collection of vehicle records, with data elements for lane of vehicle traveled, speed, time, axle spacing, axle weights and error conditions.

Managing the large volume of data generated by the sites and extracting it for reporting and analysis can be challenging. Data are collected in binary formats that can only be read by propriety software packages supplied by specific device manufacturers. This results in a lack of uniformity in reporting and precludes compilation of some historical trend data.

Mn/DOT needed a method to standardize the data from its VC and WIM sites to allow for more effective data management. Because Mn/DOT owns the devices generating VC and WIM data, it owns the data collected from these devices and can develop its own software to read the binary data collected by the devices.

What Was Our Goal?

The objective of this research was to develop a warehouse for data collected from Mn/DOT's VC and WIM sites that uses a standard format and that can accommodate current volume and expected future expansion of data collection sites. Researchers also aimed to develop data retrieval, statistical analysis and reporting utilities to support Mn/DOT's data reporting needs.

What Did We Do?

Researchers translated the proprietary binary VC and WIM data into a standardized, unified format using the ASCII character set and comma-separated value data format. ASCII, as the most widely accepted character encoding standard and data format, can be read by any text editor or spreadsheet program. As the raw binary data are decoded, the translated data are organized into a data warehouse with a hierarchical tree structure that provides a single access point for all VC and WIM data queries. Three application reporting software packages were developed to accompany the data warehouse.

What Did We Learn?

The robust data structure of the warehouse improved on prior VC and WIM data management in a number of ways. Data in the new system are easy to understand and use. The data warehouse produces outputs much more quickly than the proprietary software the new system was designed to replace, makes it easy to distribute and share large amounts of data, and is readily adaptable as data collection devices change. The new system can be installed on an unlimited number of computers without licensing concerns.

continued

“The new software solves the problem of multiple proprietary WIM systems and data formats, and allows Mn/DOT to manage large volumes of data more efficiently.”

–Benjamin Timerson,
Weight Data &
Engineering
Coordination,
Mn/DOT Office of
Transportation Data
and Analysis

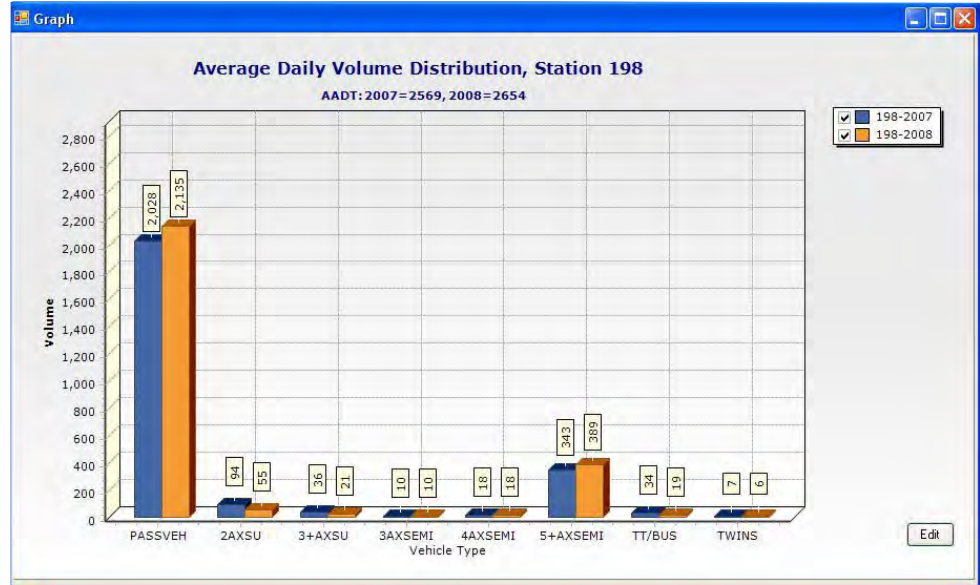
“The BullPiezo reporting package derives VC-type data such as seasonal adjustment factors from WIM data, providing Mn/DOT with additional VC data without requiring the installation of new VC data collection devices.”

–Taek Mu Kwon,
Professor, University
of Minnesota, Duluth,
Department of Electrical
and Computer
Engineering

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This plot of monthly change in average daily truck volume is an example of a graph generated by the BullPiezo reporting package.

Three reporting applications were developed as stand-alone software packages that can be installed on any computer with network access using a standard Windows installer:

- BullReport. An analysis tool for WIM data, this application includes a load spectra analysis utility for single, tandem, tridem, quadem and steer axles, and generates Traffic Monitoring Guide monthly reporting formatted for submission to FHWA. Once data in this form is produced, it can be used as inputs to other analysis tools and software packages. Summary reporting utilities are available in text, Excel, PDF and XPS Web formats.
- BullGuide. This software package was developed to generate Mechanistic-Empirical Pavement Design Guide input data using data from Mn/DOT’s WIM sites. It generates the same output files as those produced by TrafLoad, a software package that collects and processes traffic data for the MEPDG pavement design software, but produces the files more quickly and easily. BullGuide also includes a data visualization tool for analyzing export data.
- BullPiezo. Developed as a VC data application, this reporting package is capable of generating seasonal adjustment factors for short-count stations (VC sites where the counts are usually 24 to 48 hours in duration), annual average daily traffic counts and monthly average daily traffic. BullPiezo also computes SAF, AADT and MADT using WIM data, which means that Mn/DOT can generate VC-type data without installing additional VC data collection devices.

What’s Next?

The new software has been implemented in Mn/DOT’s Office of Transportation Data and Analysis. Users report significant time savings in the production of monthly reports and are looking for ways to collaborate with other Minnesota agencies to expand the use of VC and WIM data.

This Technical Summary pertains to Report 2009-33, “Development of Data Warehouse and Applications for Continuous Vehicle Class and Weigh-in-Motion Data,” published October 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200933.pdf>.



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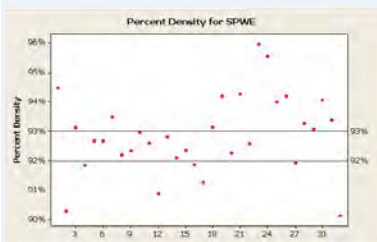
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Principal Investigator:

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University of Minnesota

PROJECT COST:

\$94,876



This scatter plot of percent density for two sample lots includes reference lines at the 100 percent pay factor limits. Densities at or above these reference lines indicate high-quality work for the pavement mix being tested.



RESEARCH
SERVICES SECTION

Statistical Methods for Materials Testing

What Was the Need?

State departments of transportation use a variety of testing protocols to assess the quality of contractors' work in the construction and rehabilitation of pavements. Mn/DOT uses one of these tests to determine the quality of compaction effort and provides incentives to contractors who achieve a high relative density in hot-mix asphalt pavement construction.

Mn/DOT's current density testing protocol for HMA divides the daily amount of pavement built by each contractor into a small number of lots. Core samples are taken from two locations in each lot, and lab tests are used to determine the relative density of each sample. The average of the two values is used as an estimate of the lot's relative density, which determines the lot's pay factor (the incentive or disincentive payments to the contractor based on the mean density of each lot). For example, a pay factor of 102 percent results in a 2 percent incentive per ton, and a 95 percent pay factor penalizes the contractor by 5 percent per ton.

It is important to employ the optimum number of tests for determining the accepted level of quality. Too few samples increase the probability of assessing an incorrect pay factor; too many samples increase testing costs and weaken the pavement. To make good payment decisions, Mn/DOT needed a reliable method to determine the number of test samples required to accurately apply the pay factors associated with the ranges of density values.

What Was Our Goal?

The goal of this study was to develop a testing protocol to determine the required number of samples that should be tested based on user-specified criteria to make more reliable pay factor calculations. A second aim was to develop guidelines for estimating key parameters needed to implement the testing protocol.

The project was not designed to propose changes to the way density values are themselves computed for a given sample or to evaluate current formulas for determining pay factors from relative density, but only to determine how many samples are needed to determine a pay factor.

What Did We Do?

Researchers reviewed current testing protocols and used Bayesian statistics to devise methods for determining how many core samples need to be evaluated using historical data about the contractor's work and reliability measures specified by the project owner as inputs.

In brief, the protocol requires dividing the range of relative densities into equal-sized intervals called bins so that each bin lies within a single pay factor range, then evaluating individual samples one by one, putting them into the appropriate bin, until the reliability measures have been met. A cutoff ratio of .6 and cutoff point of 2 means that the testing procedure will terminate when only two bins are at least 60 percent as likely as the most likely bin as calculated from the sample inputs.

Researchers developed two variations of this testing protocol to provide DOT project engineers with decision support:

- The first testing variation uses core samples, tested later in the lab, to determine pavement density where the number of tests must be known before any samples are

continued

“This new approach to testing can help Mn/DOT apply more accurate incentive and disincentive payments and reward contractors that are doing more than just meeting the minimum specifications.”

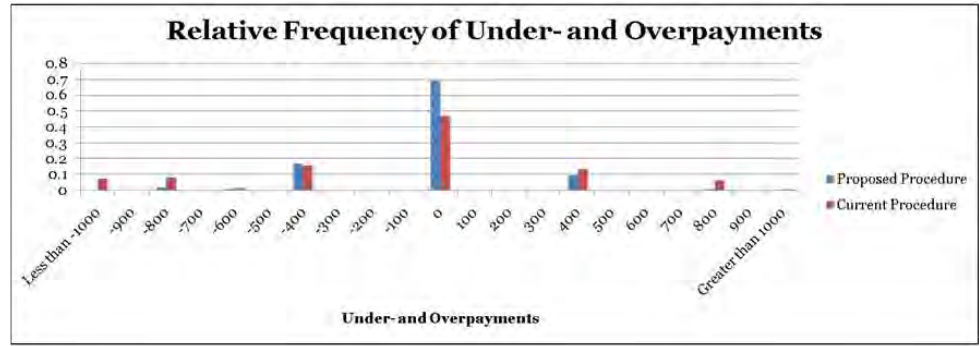
–Tom Ravn,
Director, Mn/DOT Office
of Construction and
Innovative Contracting

“With the new testing protocol, the project owner can set the criteria to determine how many samples should be taken to achieve a desired level of accuracy in identifying mean lot density.”

–Diwakar Gupta,
Professor, University of
Minnesota Institute of
Technology, Industrial &
Systems Engineering

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This graph shows the relative frequency of under- and overpayments in the current and proposed testing procedures.

obtained. A computer program calculates the number of samples that should be tested for the lot based on the reliability criteria. Test results are entered in an Excel worksheet that determines the pay factor.

- The second variation addresses testing in the field, where density observations are available immediately, for example, with the use of a nuclear density gauge that records how gamma radiation interacts with the electrons in the pavement to determine pavement density. An Excel spreadsheet uses the same data used in the first variation, augmented by the observed relative density from each test as it is taken in the field. With each test, the Excel worksheet recommends whether at least one more sample is needed to achieve the desired reliability or the procedure should terminate.

Researchers also developed a procedure to determine the initial estimate of variance of density value for each new contractor and identify when that value should change based on actual contractor performance.

What Did We Learn?

Researchers compared current and proposed testing procedures and found that the proposed testing procedure resulted in more accurate pay factor calculations. Using an example based on historical data, accuracy increased from 47 percent to 70.6 percent, where accuracy is measured by the proportion of times that the correct pay factor is identified. This translated to a change from an average over- and underpayment of \$109.60 and \$287.33 per lot to \$44.50 and \$90.74 per lot, respectively.

What's Next?

Mn/DOT continues to look for ways to improve pavement quality, and this research provides an avenue for further discussion about possible changes to specifications for materials testing. Future activities may involve providing training to contractors on the use of the new testing protocol with nuclear density gauges in the field.



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IMPLEMENTATION PROJECT COST:

\$31,997



Fliers like this one direct local public works officials to the new BMP guide posted on the LRRB Web site.



RESEARCH
SERVICES SECTION

Stormwater Maintenance Best Management Practices Resource Guide

What Was the Need?

Federal and state regulations have long required measures to control water pollution; by the late 1980s, nonpoint source pollution, such as from stormwater running off roadways, drew regulatory attention through National Pollution Discharge Elimination System permits, and state regulations increased attention on stormwater management practices.

To work well, stormwater facilities require maintenance, including periodic removal of debris and sediment. Inspections also must be conducted as problems are not always readily apparent. A retention pond brimming with water, for example, may be operating perfectly or it may be clogged; it may have filled up in one year, or it may have taken five. To the untrained eye, its condition will not be obvious. These inspections need to take place every five years, with 20 percent of state facilities inspected every year. Local agencies understand that more frequent inspection may be necessary; some specify that certain storm events will trigger a previously unscheduled inspection at certain sites considered susceptible to damage from strong storms. A rainfall of 1 inch in 30 minutes, for example, may be considered a two-year-inspection event for certain stormwater facilities.

Regulatory efforts have helped slow the continuing degradation of water quality, but have not reversed it. Despite the use of performance-based standards, there was little research to establish the performance of various stormwater designs or best management practices. Engineers lacked the hard data needed to accurately assess the costs and benefits of different stormwater management methods and determine the best approaches to keeping these systems in peak operating condition.

What Was Our Goal?

Investigators aimed to create a stormwater maintenance BMP resource guide that would describe the five most commonly used stormwater facilities in Minnesota and detail the best inspection and management practices for each. This guide would give city and county engineers a tool for use in inspecting and maintaining stormwater facilities for which they are responsible.

What Did We Implement?

Investigators and technical advisors drew upon the most current state and federal sources to assemble this description of BMPs, including the 2005 "[Minnesota Stormwater Manual](#)" and the Minnesota Pollution Control Agency's 2007 publication, "[Assessment of Stormwater Best Management Practices](#)."

How Did We Do It?

Investigators performed a literature search to gather resources on stormwater management. These materials were then reviewed and discussed by a panel of technical experts, including state and local engineers. The most relevant sources were used to assemble the resultant guide.

What Was the Impact?

The new guide, tailored to address the specific concerns of Minnesota's cities and counties, provides not just descriptions and definitions of the techniques but templates for inspection and maintenance procedures. It primarily covers five stormwater management methods:

continued

“Prior to the release of these best management practices and suggested templates for inspection reports, I think people owning and maintaining stormwater BMPs had little guidance.”

–Mark Maloney,
Public Works Director,
City of Shoreview

“This is a very hot topic with several groups conducting studies, each with a specific need and audience. We were focused on providing a resource for Minnesota’s local governments and addressed their need with a very useful guide.”

–Michael Marti,
Principal, SRF Consulting
Group, Inc.

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Bioretention facilities use natural processes to control stormwater overflow and filter pollutants.

- Stormwater ponds, which collect runoff to mitigate impact on downstream water quality.
- Bioretention, such as bioswales, rain gardens and filtration basins that use plants, soils and microbes to remove pollutants from runoff.
- Underground treatment devices, which remove grit, oil and pollutants in a variety of ways. These devices generally fit within underground drainage systems and typically suit lower volumes of runoff than generated by large storms. Often these devices are used as pretreatment systems within other BMPs.
- Underground detention systems store runoff temporarily to regulate outflow to mimic predevelopment water passage. Many such systems include pretreatment technologies for removing floatables, skimming off oil and grease, and trapping sediments in deposits. Underground treatment devices are often used in concert with underground detention systems.
- Infiltration systems temporarily trap runoff and allow it to seep into soil. Natural or constructed depressions in permeable soils, these systems employ chemical, biological and physical processes to remove pollutants.

A few technologies are also presented that are less familiar to Minnesota public works engineers, including pervious pavement, sand filtration systems and stormwater planters.

The guide will help engineers plan maintenance activities, adapt practices to local storm events and forecast costs for effective budgeting for managing these structures.

What’s Next?

Once the guide was published, investigators distributed fliers about it and posted it on the Local Road Research Board Web site. This manual is being deployed as part of the LRRB’s comprehensive stormwater road map of research, training and technical transfer to implement a performance-based approach to managing Minnesota’s stormwater. One ongoing goal is to further develop and refine a “treatment train” approach: a model that shows the effectiveness of each available BMP option given some project parameters.

This Technical Summary pertains to the LRRB-produced implementation product 2009RIC12, “Stormwater Maintenance BMP Resource Guide,” delivered January 2009. The guide can be accessed at <http://www.lrrb.org/PDF/2009RIC12.pdf>.

The manuals cited as source material for this guide include the “Minnesota Stormwater Manual,” which can be found at <http://www.pca.state.mn.us/water/stormwater/stormwater-manual.html>, and the “Assessment of Stormwater Best Management Practices,” found at <http://stormwater.safll.umn.edu/sites/stormwater.safll.umn.edu/files/asbmpfull.pdf>.



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PROJECT COST:

\$75,000



Cracks on concrete decks are a leading cause of bridge deterioration.



RESEARCH
SERVICES SECTION

Crack and Concrete Bridge Deck Sealant Performance

What Was the Need?

Sound bridge maintenance practices prolong the useful life of a bridge and increase the time between major refurbishments such as redecking. A major source of deterioration of prestressed concrete bridges is corrosion of the steel reinforcement caused by the infiltration of corrosive substances, typically chloride ions originating from deicing materials. Corrosion is caused by water seeping either through cracks or directly through the concrete, though cracks are the primary mode for corrosion of the steel reinforcement.

Minnesota's transportation agencies have been using crack and deck sealants as a preventive measure to reduce the likelihood of such bridge deterioration for some time. However, there are several types of products available and a number of application methods used. A well-researched set of best practices was needed to guide bridge engineers and maintenance personnel as they design and care for Minnesota's bridges.

What Was Our Goal?

The goal of this project was to determine the current state of the art regarding bridge deck sealants and crack sealers to extend the life of reinforced concrete bridge decks.

What Did We Do?

Researchers conducted an extensive literature review of significant studies of crack and deck sealing in concrete bridges. Subsequently, they surveyed a number of DOTs to determine common practices for the use and application of these sealants. Finally, they closely examined the results of a three-year study in Minnesota of the depth and rate of chloride penetration in concrete. The findings from these three sources were correlated and synthesized to examine trends and determine the performance characteristics, testing processes, quality assurance criteria and best application procedures for a wide range of deck and crack sealants. From this information, the research team produced a best practices guide for Minnesota's bridge deck maintenance crews on the application of deck and crack sealers on reinforced concrete bridge decks that includes specific product recommendations.

What Did We Learn?

Regarding deck sealants, the survey indicated that two tests—AASHTO T259 and ASTM C642—are commonly used to judge the acceptability of a given product. The literature indicated that the NCHRP 244 Series II test is widely used to quantify sealant performance. Research suggests that properly preparing the deck surface before the application of all types of sealant improves their effectiveness. A large scatter in the available data and the varying effectiveness of each of the considered sealants relative to a particular application prevent the identification of a single sealant that will work best in all situations. Some of the research team's significant conclusions and recommendations based on the overall trends were:

- Among the solvent-based sealers, silane products typically outperform siloxane products.
- Water-based products are not suitable for reapplication.
- Solvent-based products typically outperform water-based products.
- High solids content in the sealer typically improves performance.

Researchers found that the sealant S40Si comes closest to fitting the above criteria.

continued

“Bridge life is controlled by controlling cracks.”

–Jim Lilly,
Bridge Standards,
Research and
Information Manager,
Mn/DOT Office of Bridges
and Structures

“Crack sealing is a targeted maintenance activity for our bridges, but we needed more detailed knowledge of the properties of different products and some clear recommendations for their use in specific cases.”

–Gary Peterson,
Mn/DOT Assistant Bridge
Design Engineer (retired)
and former Technical
Liaison

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Sealing cracks in concrete decks is a routine part of bridge maintenance, but practices and products vary significantly. This study established best practices guidelines for concrete deck and crack sealing on Minnesota’s bridges.

Regarding crack sealers, researchers found that very little acceptance testing was done for selecting them, with many states simply relying on field experience and reviewing previous laboratory and field research. As with deck sealants, proper preparation of the surfaces and cracks themselves improved the performance of the sealer. Among the findings from the current research and the surveys were:

- High molecular weight methacrylate products provide better penetration in smaller cracks.
- Epoxy sealers typically provide higher bond strength and demonstrate good resistance to freeze-thaw effects in laboratory tests.
- Laboratory results were frequently at odds with field studies; field performance was much poorer than laboratory performance for HMWM products. Little field research has been done with epoxy sealers.

Researchers recommended that further research be conducted to clarify the (sometimes contradictory) findings in the existing studies of crack sealants, especially to coordinate laboratory and field testing of products and application techniques.

What’s Next?

A new project implementing and expanding upon these findings is currently in the scoping phase. In this project, 10 concrete crack sealant products will be field-tested and evaluated for performance; the previous studies synthesized in the current project focused largely on laboratory testing. This new project will serve to validate and optimize practices that Minnesota field crews already use and will result in final recommendations of the best products and methods regarding crack sealants in Minnesota.

This Technical Summary pertains to Report 2009-13, “Crack and Concrete Deck Sealant Performance,” published March 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200913.pdf>. The implementation project mentioned is 2009-159, “Implementation of Best Performing Concrete Bridge Deck Crack Sealants.” For more information, contact research@dot.state.mn.us.



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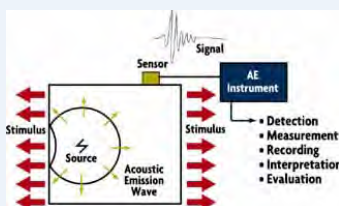
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Principal Investigator:

Arturo Schultz, University of Minnesota

PROJECT COST:

\$143,160



Acoustic instrumentation (schematized above) is just one of many systems available to bridge owners for monitoring the structural health of bridges.

Bridge Health Monitoring and Inspection: A Survey of Methods

What Was the Need?

In the wake of the I-35W bridge collapse in August 2007, bridge designers, engineers and caretakers have intensified their interest in techniques and equipment for monitoring bridge health that complement standard inspections. Aging infrastructure also requires more frequent and careful monitoring to assure both public safety and proper performance. Techniques and applications for remote monitoring vary widely and address both short-term changes in bridge structure and the assessment of long-term performance. Mn/DOT has funded projects examining a variety of monitoring techniques including the measurement of distortional fatigue, wind-induced vibrations and soil pressures.

Increasing the frequency of hands-on inspection of Minnesota's hundreds of aging bridges is both costly and an impractical burden for bridge engineers and inspectors. Many companies sell products and services that can aid bridge engineers in assessing the health of bridges more thoroughly and more frequently. However, in the face of the daunting number and variety of products and applications available, an obstacle for the adoption of these technologies is the absence of comprehensive criteria for evaluating and selecting the technologies.

What Was Our Goal?

The objectives of this project were to generate criteria for the evaluation and selection of bridge monitoring technologies and systems, and to develop a program to aid engineers in assessing which commercially available bridge monitoring technologies are most appropriate for a given site.

What Did We Do?

Bridge health monitoring instrumentation and techniques vary according to the time frame and physical scale of the monitoring.

- The monitoring time frame may be more or less than a year (classified as long term or short term) or part of a regularly scheduled inspection of components. Regular monitoring tracks the time development of particular measures such as the growth of known cracks or the spread of known corrosion. Early warning systems for bridge owners or collapse warning systems for motorists would provide notification if measured parameters exceed predetermined ranges.
- The physical scale of monitoring can vary from the examination of specific locations in the bridge (for instance, known cracks or corrosion at specific locations) to monitoring the motion and integrity of individual structural members (such as girders or decks), to global monitoring of the entire bridge structure. Instrumentation varies based upon the application. Some examples of different types of scans are acoustic emission, vibrating wire strain gauges, 3-D laser scanning, ground penetrating radar, fiber optic sensors and macrocell corrosion rate sensors.

Researchers worked with staff from Mn/DOT's Office of Bridges and Structures to develop a clear and detailed understanding of their inspection and monitoring needs, leading to the development of robust criteria for selection and evaluation of monitoring technologies. Researchers developed a questionnaire for monitoring system vendors to characterize the different types of systems and services that are commercially available. The nature and time frame of the monitoring, the specific parameters measured and the expected application of the acquired information formed essential parts of this survey.

continued

“This research gave us a process and a tool to make more informed decisions about monitoring products without needing a bevy of experts in the bridge office.”

—Gary Peterson,
Mn/DOT Assistant Bridge
Design Engineer (retired)

“Monitoring systems that can automatically and reliably warn the owner when failure is imminent have yet to be developed and may become a very useful tool in the future.”

—Arturo Schultz,
Professor, University of
Minnesota Department
of Civil Engineering

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The collapse of the I-35W bridge (left) in August 2007 intensified the interest in bridge health monitoring. In this project, researchers helped Mn/DOT staff evaluate the instrumentation proposed for monitoring the new St. Anthony Falls Bridge (right), which opened in September 2008.

Overall, the questionnaire sought information on the major uses, components and goals of the equipment and software that define a given vendor’s monitoring system.

Questionnaires were sent to 72 vendors, and 38 completed them. Researchers focused on vendors that offer complete monitoring systems, which are composed of a control unit, sensors, communication and software.

Based on the selection criteria, researchers then developed a spreadsheet-based tool, implemented in Microsoft Excel, to help bridge owners determine which companies offer systems that fit their particular needs, matching each owner’s desires to company specifics that were returned in the questionnaire and listing the companies that best fit the owner’s needs. The evaluation of the products and services offered is left to the bridge owner.

What Did We Learn?

While many products are available, most systems would serve as components of a global monitoring strategy that needs to be developed independently. Specific monitoring needs like crack width and girder strain are addressed, but judgments regarding bridge health require further evaluation of the output from these monitoring systems. In particular, reliable, robust systems for warning of imminent collapse have yet to be developed and will likely be a system composed of the pieces that are currently available.

What’s Next?

The database is being used to aid in the selection of monitoring equipment. The researchers have since participated in the selection and deployment of strain-gauge monitoring on the Wakota Bridge in the southeast Minneapolis/St. Paul area.



RESEARCH SERVICES SECTION

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PROJECT COST:

\$153,900



Pile capacity can increase significantly because pore water pressure created during pile driving dissipates and increases soil strength.

Increasing Pile Driving Efficiency for Bridge Foundations

What Was the Need?

To create a foundation for a bridge, construction crews typically drive piles—poles consisting of wood, concrete or steel—into the ground, hammering each pile to a depth at which the friction between its surface and the surrounding soil will create enough grip to bear the load above it. Pile capacity, the load the pile can support, is measured by the behavior of the pile as it is driven into the ground. Each hammer blow can be treated as a load test in which pile capacity is a function of the weight of the hammer and height from which it falls as well as the weight of the pile and the depth to which it is driven.

The dynamic function relating these factors to pile capacity is given as a mathematical formula. Most states, including Minnesota, use a variation of a pile driving formula developed in the 1930s by the Engineering News Record. This formula does not have a high degree of accuracy, and the accuracy of Mn/DOT's modification of the formula has never been thoroughly evaluated. This evaluation is necessary as part of Minnesota's Federal Highway Administration-mandated transition to Load Resistance Factor Design, which requires the use of more accurate load and resistance factors calculated from actual pile load tests.

Research was also needed to account for side shear "setup," which is the increase in pile capacity that frequently occurs with the passage of a few days or weeks after driving. Failing to consider setup in determining whether capacity requirements have been met often results in driving piles deeper than necessary, creating unnecessary effort and expense.

What Was Our Goal?

The objectives of this research were to conduct a systematic evaluation of Mn/DOT's pile driving formula resistance factor and to investigate field and laboratory tests for predicting the magnitude and rate of anticipated pile setup.

What Did We Do?

Researchers first established Mn/DOT's current practices for pile design and construction by reviewing its bridge construction manual, conducting interviews with Mn/DOT personnel and contractors, and compiling and analyzing construction records for 28 bridges. Then they assembled a data set of 270 pile capacity case histories nationwide that included detailed pile driving system and resistance characteristics as well as field measurements of pile capacities via static load tests to failure.

Researchers evaluated the performance of various pile driving formulas by how well they predicted the field measurements in this data set. These formulas included ENR, Gates, FHWA-modified Gates, and those used by Washington State DOT and Mn/DOT. Finally, researchers used these results to develop a modified load resistance factor for use in Mn/DOT's pile driving formula.

To investigate methods for estimating side shear setup, researchers conducted a literature search and also surveyed state DOTs concerning the field and laboratory tests they used to estimate the magnitude and rate of setup.

What Did We Learn?

Results showed that Mn/DOT's pile driving formulas tended to overpredict pile capacity, and researchers suggested making this formula more reliable by significantly reducing its load resistance factor. Even with this modification, using this formula under LRFD

continued

“Not only did researchers develop a new load resistance factor for the pile driving formula, but they went a step further in developing an entirely new formula that could lead to safer designs and potentially significant cost savings for Mn/DOT.”

—Gary Person,
Mn/DOT Foundations
Engineer

“Estimating the effects of setup in increasing pile capacity is a promising new area of research that could significantly reduce the effort and material costs involved in pile driving.”

—Aaron Budge,
Associate Professor,
Minnesota State
University—Mankato
Department of
Mechanical and Civil
Engineering

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Construction crews need to drive piles deep enough to provide support for a bridge while not overdriving, which wastes resources.

would involve increased effort and materials costs, so researchers also developed a new dynamic formula by performing a linear regression analysis on the data set used in this project. Then they compared the performance of this proposed new formula to that of the existing Mn/DOT formulas and showed that moving to the new formula would lead to more consistent results, which translate to safer designs and potential cost savings.

Setup literature search results showed that side shear setup occurs in most soil types and with most types of piles, and can increase capacity from as little as 20 percent to as much as 800 percent. Factors causing setup can include the dissipation of pore water pressure generated during pile driving and consequent increase in soil strength with time, and the disturbance in soil surrounding piles caused by its displacement during driving. Survey results showed that while very few states are using field and laboratory tests to estimate setup, such methods are being investigated and show promise for application in the near future.

What's Next?

Mn/DOT has funded an implementation project to collect pile driving field data and compare the results to those from recent research performed by other states.

Researchers recommend a transition period in field practices of pile monitoring. The existing Mn/DOT equation using resistance factors ($\phi=0.40$ for h-pile and $\phi=0.25$ for pipe pile) should be examined against the new equation and the associated resistance factors ($\phi=0.6$ for h-piles and $\phi=0.45$ for pipe piles). A longer-term testing program of dynamic and, where possible, static load testing should be implemented to evaluate and review the proposed methodologies. Taking into account the effects of setup could significantly decrease the cost and effort involved in bridge construction.

This Technical Summary pertains to Reports 2009-37, “Developing a Resistance Factor for Mn/DOT’s Pile Driving Formula,” published in November 2009, and 2009-38, “Study of Pile Setup Evaluation Methods,” published in December 2009. The full reports can be accessed at <http://www.lrrb.org/PDF/200937.pdf> and <http://www.lrrb.org/PDF/200938.pdf>, respectively.



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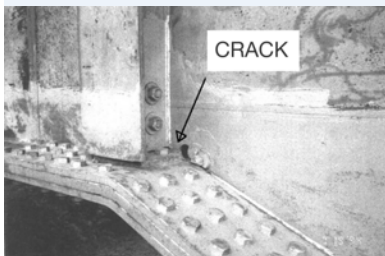
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Principal Investigator:

Arturo Schultz, University of Minnesota

PROJECT COST:

\$35,630



Haunch insert cracking on the Lexington Avenue Bridge is one of the 18 fatigue-critical details that will be represented in Pontis.

Putting Research into Practice: Implementing a Fatigue Detail Classification Scheme for Mn/DOT's Steel Bridges

What Was the Need?

Many steel bridges throughout the country, particularly those constructed before the 1990s, are approaching an age when fatigue life of certain details will be reached, making these bridges vulnerable to fatigue and fracture problems.

Current data used by the Mn/DOT Bridge Office to recommend bridge repair or replacement does not indicate which steel bridges have a high potential for fatigue problems. As a result, Mn/DOT cannot be proactive and recommend the necessary maintenance actions to prevent problems from occurring. Instead, repairs are made to fix damage.

Mn/DOT needs a cost-effective method to obtain additional information about its steel bridges that will provide for an accurate inventory of fatigue details. Understanding how fatigue details affect overall bridge inventory life will help Mn/DOT improve the accuracy of repair recommendations, focus inspection efforts and estimate future spending.

What Was Our Goal?

The goal of this project was to maximize the value of previous research by implementing a scheme that ranks steel bridges based on the frequency and severity of the most common fracture and fatigue-sensitive details that are present in each bridge. The gross ranking of bridges with high, medium or low need for preventive maintenance or special inspection will be used by bridge inspectors and those responsible for managing Minnesota's steel bridge inventory.

What Did We Implement?

Mn/DOT leveraged two important resources for this project:

- "Incorporation of Fatigue Detail Classification of Steel Bridges into the Minnesota Department of Transportation Database" (2007-22), which provided a classification scheme for ranking the fatigue and fracture susceptibility of steel bridges in the Mn/DOT inventory.
- The Pontis Bridge Management System. Developed under a Federal Highway Administration contract, Mn/DOT has used Pontis since 1994 to store information about the condition of structural elements such as beams, pier columns and decks.

How Did We Do It?

Work began on the project with a review of the more than 1,000 steel bridges in Minnesota's trunk highway system. For each steel bridge, bridge plans and inspection reports were examined to determine if any of the 18 commonly occurring fatigue/fracture-prone details identified in the 2007 research project (which include cover plates that terminate in tension flanges, and intermittent and tack welds) were present.

Data about material properties and detail geometry of the 18 fatigue details were entered into an Excel spreadsheet-based program. Additional details about each bridge were also documented, such as the paint system, bridge steel, girder depth, number of beams, railing toggles and the bridge plan's specification year.

continued

“This conceptually simple idea—gathering and classifying data from bridge plans and inspection records—means that important information will be readily available to help Mn/DOT manage its steel bridge inventory.”

–Jim Pierce,
Mn/DOT Bridge
Management Engineer

“Bridge managers can organize bridges by vulnerability using the composite rank numbers that represent overall bridge susceptibility to fatigue and fracture based on the details the bridge possesses.”

–Arturo Schultz,
Professor, University of
Minnesota Department
of Civil Engineering

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DETAIL NAME	INPUT	INPUT TYPE	WORST CASE	RANK NO.
Transverse Stiffener Web Gap		(Y/blank)	Y	0
Gap flange		(top/bot)	top	
Bridge span skew		(deg)		
Span length containing web gap		(ft)		
Web gap height		(in)		
Girder web thickness		(in)		
Insufficient Cope Radius	Y	(Y/blank)	Y	2
Is there a cope radius specified?	N	(Y/N)	N	
Cope radius (0 if none)	0	(in)		
Partial Length Cover Plate	Y	(Y/blank)	Y	3
Girder flange thickness	1.570	(in)		
Girder flange width	16.595	(in)		
Is the end tapered	Y	(Y/N)	N	
Cover plate width	13	(in)		
Is there a weld across end of cover plate	Y	(Y/N)	N	
Shelf Plate Welded to Girder Web		(Y/blank)	Y	0
Weld termination and cope distances within Detail B41 allowable dim.		(Y/N)	N	
Is any plate intersected or coped around shelf plate		(Y/N)	Y	
Length of shelf plate		(in)		
Thickness of shelf plate		(in)		
Shelf plate transition radius		(in)		
Stringer or Truss Floor-beam Bracket		(Y/blank)	Y	0
Floor beam connected to stringer		(Y/N)	Y	

This spreadsheet reflects the results of an Excel-based program that uses data about a bridge’s fatigue-critical details to calculate detail-specific rank numbers from 0 to 4 and a composite rank number that indicates the overall fracture sensitivity of a bridge.

What Was the Impact?

The Excel program’s formulas rank each of the 18 fatigue details with a number from 0 (no history of cracking) to 4 (high danger of fracture without warning). The program also computes a composite rank number for each steel bridge in the Mn/DOT inventory as the sum of the rank numbers for the most severe of each detail type, with possible composite rankings ranging from 0 to 54. A higher composite rank number indicates a more fracture-sensitive bridge.

Output of the Excel program takes two forms: a spreadsheet that presents the rank score of each fatigue detail and the composite rank of the bridge; and a single, comma-delimited line of information for each bridge that can be easily transferred to a database as a text file.

The program makes information easy to gather and access. A blank copy of the program interface can be printed and used as a questionnaire by staff examining bridge plans or performing a field inspection to record data about fatigue details that can then be entered into the ranking program. The spreadsheet generated by the ranking program makes it easy to quickly identify the detail with the most severe problems for each bridge.

Mn/DOT anticipates many uses for the new data. The rank numbers can be used to assess the scope of individual bridge preservation projects and identify bridges most likely to fatigue, and identify details requiring special attention during inspection. Costs can be cut by using a single contract that incorporates the repair of fatigue-susceptible components with general maintenance such as deck repair. Bridge engineers can also quickly gauge the effects of certain load configurations and identify bridges that would require replacement in the event of weight increases.

What’s Next?

The fatigue-critical rank data and other bridge details documented by this project are expected to be uploaded and stored in Pontis by summer 2009.

This Technical Summary pertains to the implementation project MPR-6(036), “Implementation of Steel Bridge Maintenance Planning,” completed December 2008. For more information about this project, contact Jim Pierce at james.pierce@dot.state.mn.us.

The research being implemented via this project can be found in Report 2007-22, “Incorporation of Fatigue Detail Classification of Steel Bridges into the Minnesota Department of Transportation Database,” published June 2007. The full report can be accessed at <http://www.lrrb.org/PDF/200722.pdf>.



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PROJECT COST:

\$49,685



Sand patch testing involves spreading a set volume of sand to measure surface texture.



RESEARCH
SERVICES SECTION

Preventive Maintenance for Recreational Trails

What Was the Need?

Minnesota's nationally recognized regional park system contains more than 25,000 miles of city, county and state-owned recreational trails. These trails are vital to the quality of life of Minnesotans, providing exercise and recreation for walkers, runners, cyclists and inline skaters alike. The trails also play an important role in the economies of surrounding communities, increasing the attractiveness and property values of adjacent areas as well as attracting tourists and encouraging trail-related purchases such as bicycles.

The funds available for recreational trails are limited and over the last 20 years have been dedicated to new construction rather than maintenance. Consequently, there is a growing interest in low-cost preventive maintenance techniques that can extend the useful service lives of trails without compromising the quality of their surfaces. This task is especially challenging given the variety of users that trails accommodate. For example, while walkers can use relatively rough trails, inline skaters cannot. Further, current preventive maintenance techniques have been adapted from methods developed for highways and other roads without the average trail user in mind.

What Was Our Goal?

The goals of this project were to evaluate the effectiveness of available pavement preventive maintenance techniques for recreational trails, and to establish which treatment methods and sealants best balanced trail preservation with acceptable surface conditions for the widest variety of trail users.

What Did We Do?

Researchers first compiled a list of commonly used sealant products and surface and crack treatment methods that have been designed for the preventive maintenance of roadways but have also been applied to recreational trails. Surface treatments—such as fog seals, chip seals, slurry seals and microsurfacing—involve covering existing pavements with various kinds of asphalt emulsions and possibly adding an additional layer of gravel or crushed aggregate. Crack treatments involve various techniques for filling cracks with sealants. These treatments are designed to slow the damage caused by exposure of pavements to water and sunlight, which can oxidize and harden pavement binders, making surfaces brittle and prone to cracking and other deterioration.

In 2008, researchers applied selected treatments to 18 test sections, ranging in length from 150 feet to 1 mile, on seven recreational trails in Minnesota. These treatments were evaluated for ease of application; after application, they were evaluated in comparison to control sections for how effectively they sealed against water, how smooth or rough they made the resulting pavement texture, and how trail users felt about the new surface.

To establish how well pavements prevented the infiltration of water, researchers evaluated their permeability using a falling-head field permeameter, which measures how long it takes for a given amount of water to flow into a pavement. To evaluate how treatments affected surface texture, researchers used the ASTM E965 sand patch test, which reports the diameter of a uniformly spread volume of sand: Larger diameters correspond to less texture and smaller diameters to greater texture.

What Did We Learn?

Results showed that pavement preservation treatments normally used on streets and highways can be successfully modified for use on recreational trails. All of the treat-

continued

“This project gave us practical demonstrations in the field of the importance of using preventive maintenance techniques early on in the life of recreational trails. Doing so can significantly slow pavement aging over subsequent years.”

—Roger Olson,
Engineer, Mn/DOT Office
of Materials and Road
Research

“Because it gives personnel responsible for recreational trails additional tools for making cost/benefit maintenance decisions, this research has produced a lot of interest in Minnesota, and the potential audience for its results is worldwide.”

—Duane Schwartz,
Public Works Director,
City of Roseville

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Designed for roadways, many treatments must be modified for use on recreational trails. For example, chip sealing should be scheduled during the latter part of the summer when trails are at maximum strength and should use a reduced chip size to yield a smoother surface.

ments reduced the permeability of trail surfaces compared to control sections, and so are expected to reduce damage caused by sun and water. All spray-applied fog seals reduced permeability while decreasing pavement texture; this will extend the trail’s surface life. While chip seals increased pavement texture due to the addition of aggregate, they can be modified with a reduced chip size—such as sand—to limit this increase.

Researchers recommend preventive maintenance early in a pavement’s life while it is still in good condition, beginning at construction and continuing on a regular basis. An application at the time of construction, which can be done as part of the construction contract, seals initial surface voids, retarding aging until the next retreatment. Later re-sealing can be performed while sealing nearby streets to maximize economies of scale.

Because of the short-term nature of this study, researchers were unable to determine which treatment products would be most cost-effective over the pavement life cycle. All of the tested products resulted in a quality surface for users and are expected to help deter the effects of aging.

What’s Next?

An LRRB project is currently planned to create a training workshop on trail corridor management that will incorporate the results of this study.

Researchers recommend monitoring trails over the next three to five years to determine which treatments performed best. They also recommend further research to develop mix designs optimized for recreational trails and establish the most effective sealants for sealing trail cracks that can cause tripping and other safety hazards.

This Technical Summary pertains to the LRRB-produced Report 2009-25, “Preventative Maintenance for Recreational Trails,” published July 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200925.pdf>.



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PROJECT COST:

\$118,908



Researchers studied user-activated warning crosswalks such as this one in Woodbury, Minnesota.



Evaluating Active and Passive Crosswalk Warnings at Unsignalized Intersections and Mid-Block Sites

What Was the Need?

A growing interest in walking and bicycling in Minnesota has led to a need to evaluate the safety and usability of pedestrian and bicycling facilities. One area that has received considerable attention is crosswalk safety at intersections without traffic signals or at mid-block sites.

Warnings at uncontrolled crosswalks are intended to promote caution in approaching drivers. Passive warning crosswalk sites feature roadway markings accompanied by yellow pedestrian warning signs facing oncoming traffic. Active warning sites feature these passive warnings accompanied by a flashing light attached to a roadway shoulder sign or suspended above the roadway. The light either flashes continuously or is activated by a pedestrian or bicyclist wishing to use the crosswalk. Passive warning installations typically cost no more than \$500; the cost to install an active warning system ranges from \$5,000 to \$12,000.

Previous studies into the safety effect of passive and active warnings at these types of sites have provided no clear guidance. If new research shows that passive warnings are as effective as active warning systems in safeguarding pedestrians and bicyclists using uncontrolled crosswalks, Minnesota's cities and counties could save money by installing lower-cost passive warning systems.

What Was Our Goal?

The objectives of this study were to:

- Review literature to evaluate research findings relevant to crosswalk warning systems.
- Conduct a field study of the relative benefits of active and passive warnings at selected suburban and urban pedestrian crosswalk sites.
- Develop recommendations and design alternatives for low-cost pedestrian crosswalk warnings.

What Did We Do?

From July through November 2007, researchers collected data at 18 pedestrian crosswalk sites in the Twin Cities metropolitan area that had roadway speed limits of 25 mph, 30 mph or 35 mph, some with passive and some with active warning systems. Monitoring took place during daylight hours when pedestrian and bicyclist traffic was expected, with observation periods ranging from 50 to 110 minutes. Data from 7,305 vehicle crosswalk and 596 vehicle-pedestrian interactions were recorded.

Researchers used two novel technologies for this project. First, a modular, portable camera boom system, affixed to the back of a vehicle with a trailer hitch, allowed researchers to gather video data of vehicle behavior. Then they used a computer vision software platform to analyze the video. The program identifies and tracks an object as it changes position from frame to frame across successively recorded 30 frames/second camera images; it uses this tracking information to automatically compute distances, velocities and accelerations of moving vehicles, and vehicle and pedestrian counts. The result is an automated collection of a large amount of sophisticated data that can be used to calculate average vehicle velocities and deceleration/acceleration values for each interaction. This allowed researchers to produce an aggregate comparison of behavior at intersections

continued

“This study found no significant difference in active and passive warning systems in promoting more cautious driving behavior at uncontrolled crosswalks.”

–Deb Bloom,
City Engineer,
City of Roseville

“When it comes to designing warning systems for uncontrolled pedestrian crosswalks, the presence or absence of the crosswalk user, not the warning itself, has the greatest influence on the driving behavior of motorists approaching the crosswalk.”

–Thomas Smith,
Research Associate,
University of Minnesota
School of Kinesiology

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Researchers used a portable camera boom system to gather observational data on vehicle-crosswalk and vehicle-pedestrian interactions at uncontrolled crosswalks in the Twin Cities metropolitan area.

with passive versus active warning systems, as well as the behavior of drivers when a pedestrian or bicyclist was present or absent.

What Did We Learn?

The findings of this project were mixed. No significant differences in overall velocities and deceleration/acceleration values were noted between drivers at intersections with active and passive warnings, whether or not a pedestrian or bicyclist was present. However, drivers approaching uncontrolled crosswalks with active warnings, particularly user-activated warnings, tended to drive more slowly than drivers approaching crosswalks with passive warnings. This supports the current practice of installing these more expensive systems at sites with higher vehicular traffic, where more vehicle/pedestrian interaction is expected. User-activated warnings were not activated by pedestrians.

Researchers believe the ambiguity of warning signs at uncontrolled crosswalks accounts for the study’s mixed results; these signs refer to an event (someone crossing the street) that may or may not occur at the time the motorist approaches the crosswalk. Because of this ambiguity, most motorists approaching an uncontrolled crosswalk tend to pay attention to whether or not a pedestrian or bicyclist is present, not to the type of warning.

What’s Next

A prevailing perception that active warning systems are more beneficial than passive warnings in safeguarding pedestrians and bicyclists at uncontrolled crosswalks was not validated by this study. More research is needed to establish guidelines based on empirical evidence for choosing warning systems at these crosswalks.

An effective solution to safeguard pedestrians and bicyclists may lie in the development of a crosswalk active warning system where the flashing light is activated automatically by the presence of a pedestrian or bicyclist near the crosswalk. Further efforts to enhance safety might include an evaluation of motorist and non-motorist understanding of pedestrian right-of-way laws and the vehicle code, and development of an educational program to promote more cautious driver behavior at uncontrolled crosswalks.

This Technical Summary pertains to the LRRB-produced Report 2009-03, “Warning Efficacy of Active Versus Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Crosswalks,” published January 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200903.pdf>.



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Robert Edstrom, Mn/DOT

PROJECT COST:

\$57,872



Water samples were collected unfiltered in precleaned polyethylene bottles and kept on ice until delivered to the laboratory.



RESEARCH
SERVICES SECTION

Assessing the Environmental Impact of Tire Shreds Used Below the Water Table in Road Base Fills

What Was the Need?

Scrap tires are sometimes recycled by being shredded and reused for a number of purposes, including in artificial reefs and as a lightweight fill material for road base construction. Mn/DOT currently uses tire shreds for road bases constructed above the groundwater table through a standing beneficial use determination from the Minnesota Pollution Control Agency. Recent studies have also shown promise for using tire shreds below the water table as a buoyant lightweight fill in wet road bases.

However, it is not currently legal in Minnesota to use tire shreds below the groundwater table because it is not clear to what extent tire shreds leach chemicals into surface and groundwater. While several laboratory and field studies have analyzed tire shred leachate for inorganic materials, organic chemical content has not been comprehensively studied. Further, only a few projects have studied the toxicity of this leachate to aquatic life.

More research was needed on the environmental impacts of tire shreds before they could be used for road construction below the groundwater table.

What Was Our Goal?

The purpose of this study was to determine the environmental effects of chemicals leached from tire shred materials placed below the seasonal groundwater table for use as a lightweight fill in wet road bases.

What Did We Do?

In November 2002, Mn/DOT constructed a low-traffic-volume road section using more than 7 million pounds of tire shreds from a mixture of glass- and steel-belted tires. These tire shreds were enclosed in a geotextile fabric and placed in the road base. Mn/DOT then installed groundwater monitoring wells near this site as well as one background control well.

After three years, researchers analyzed surface and adjacent well water samples for numerous properties, including pH, temperature, metal content and the levels of eight semivolatile organic chemicals identified in other tire material field studies.

What Did We Learn?

Results indicated elevated surface and groundwater chemical concentrations and metal levels, including for chemical oxygen demand, total suspended solids, specific conductance, barium, iron and manganese. Researchers also found an increase in levels of four out of eight of the tire-related semivolatile organic chemicals: aniline, benzothiazole, 2-hydroxybenzothiazole and 4-acetylmorpholine. The concentration of aniline was of particular concern since it exceeded the limit of 10 parts per billion prescribed by state drinking water regulations.

These materials appeared to be leached from the road base, and their concentrations varied in proportion with the thickness of submerged tire shreds. However, concentrations were largely retained within the geotextile fabric wrap. While none of the tire-related organic chemicals was detected in samples collected outside of the road base, barium, iron, manganese and possibly zinc appeared to be migrating beyond the fabric wrap.

continued

“This study was unique in its scale and longevity, and yielded important results not measured in previous studies, including the aniline levels, which are critical to drinking water regulations.”

—Robert Edstrom,
Chief Toxicologist,
Mn/DOT Office of
Environmental Services

“Minnesota counties were concerned about leaching from its tire shreds projects but didn’t have any real data. This effort provided an opportunity to evaluate the real-world response to tire shreds, both chemical and biological, of the aquatic environment.”

—Dan Warzala,
Research Project
Coordinator, Mn/DOT
Office of Policy Analysis,
Research & Innovation

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Shredded tires were placed within a layer of geotextile permeable fabric and enclosed in “burrito wrap” fashion to form the new road base. This wrap was used to keep the tire material from migrating into the soft undersoils.

Researchers also found significant levels of ammonia in the groundwater, but could not positively identify its source. Although the ammonia may have originated from a sod farm adjacent to the study area, the relatively consistent and elevated concentrations found in the ground as opposed to surface water suggested that tire shreds were a possible source.

Finally, while leached organic materials did not affect the viability of all vertebrates—midge, for instance, appeared unaffected—ecotoxicity testing showed an increase in the mortality of fathead minnows as well as a negative effect on the mortality and reproductive rates of water fleas. This toxicity also appeared to be largely confined within the road base fabric wrap.

What’s Next?

This study is unique in that no other field studies have used a geotextile fabric wrap or such a large mass of tire shreds. Results showed that the use of this wrap was environmentally beneficial, limiting the leaching of chemicals from tire shreds by restricting water flow through the road base.

Further, while most studies have measured the environmental effects of tire shreds only within the first 24 months of placement, this study monitored the water quality from the third year to the fifth year of the road base life cycle. These field results have now been made available to resource managers nationwide, so that they may be used to assess the accuracy of bench-scale studies.

Additional research is needed into how harmful tire shred leachates are to the environment, and in a follow-up study already under way, researchers plan to continue to look for similar studies nationwide to assess leachate toxicity. Researchers also recommend continued monitoring of the study’s key parameters, including aniline, specific conductivity and total organic carbon.

This Technical Summary pertains to the LRRB-produced Report 2009-02, “Oak Grove Tire Shreds Project: Tire Shreds below the Seasonal Groundwater Table, Years 2006-2008,” published November 2008. The full report can be accessed at <http://www.lrrb.org/PDF/200902.pdf>.



RESEARCH SERVICES SECTION

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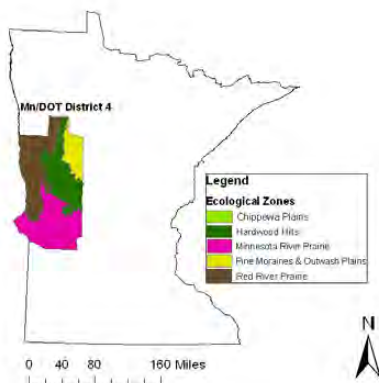
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John Nieber, University of Minnesota
Donald Wyse, University of Minnesota

IMPLEMENTATION PROJECT COST:

\$20,270



Field surveys were conducted within the ecological zone boundaries of Mn/DOT District 4 of Minnesota.

Putting Research into Practice: Refining Noxious Weed Management

What Was the Need?

Mn/DOT is required by law to manage certain noxious weeds along its highways. By controlling weeds, Mn/DOT can reduce roadside maintenance costs and provide environmental and safety benefits to maintain a healthy roadside. Because resources for managing weeds are limited, managers must have effective tools for identifying the locations where infestations are most severe, as well as for identifying the most effective techniques for each situation. However, determining the location and distribution of weeds over the large areas comprising highway rights-of-way can be costly and time-consuming.

A research effort was initiated in 2000 to conduct yearly surveys of noxious weeds using handheld Global Positioning System devices along a sample of 3-mile road segments in several western Minnesota counties, extrapolating from this data to predict infestations across an entire Mn/DOT district. The sampling method was refined to improve its accuracy and efficiency, but more work was still required to finalize the sampling design.

What Was Our Goal?

The goal of this implementation effort was to further develop recommendations for a more efficient, cost-effective method of quantifying the density of noxious weed infestations. This stage of the project required a comparison of the efficiencies of two recently used sampling plans: one measuring weed population **density** (area infested per unit length of highway) over 100 225-foot segments; and the other, potentially less labor-intensive, method measuring weed population **distribution** (presence or absence of weeds) over 150 14-foot segments.

What Did We Implement?

This project implemented the findings of an earlier Mn/DOT study, "Management Practices for Weed Control in Roadway Rights-of-Way" (2007-42), published October 2007. This study evaluated weed surveys taken during 2004 and 2005 to compare:

- The method used from 2000 to 2004, which involved evaluation of infestations over 3-mile-long segments
- A new method that used greater numbers of smaller, 1/4-mile-long segments

The study showed that the older method was less precise, and researchers predicted via statistical analysis that sampling precision would be further improved by using even smaller segments of 225 feet or less.

How Did We Do It?

In the summer of 2007, Mn/DOT District 4 personnel conducted field surveys in the same areas that had been previously surveyed in 2004 and 2005, using GPS devices to map the population distribution of 13 noxious weed species in rights-of-way on highways managed by Mn/DOT. Surveyors mapped 100 sampling sites in 225-foot-long segments for population density, recording patch area, location, landscape position, and the number and species of weeds within the segment. They also mapped 150 sampling sites in 14-foot-long segments for population distribution, or presence-absence data, noting which segments had at least one weed and which segments had none.

Investigators used this data to determine how well the Kono and Sugino mathematical model could be used to predict population density from population distribution. To do

continued

“This project gets us closer to applying a systems approach to reducing weed numbers by establishing a solid performance measure for evaluating weed management methods on a district basis.”

—Paul Walvatne,
Supervisor, Mn/DOT
Roadside Vegetation
Management Unit

“Results currently suggest that measuring weed infestations using 225-foot surveys is more efficient than using 14-foot surveys, although further data will help establish these results more conclusively.”

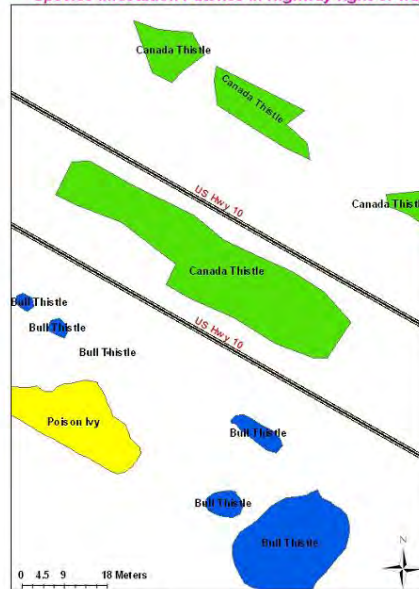
—Donald Wyse,
Professor, University of
Minnesota Department
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Weed Infestations along Highway right-of-way
Species Infestation Patches in Highway right-of-way



Investigators used the 225-foot sampling approach to map the distribution of species infestation patches in a segment of the US 10 right-of-way.

so, they first calibrated the model by dividing data recorded with 225-foot segments into 14-foot segments, determining the proportion of these subdivisions that were infested, and then relating these proportions to the population densities of the 225-foot segments of which they were a part. Once calibrated, this model was applied to population density data collected from actual 14-foot segments to calculate population densities and measure the accuracy of these calculations against expected results.

What Was the Impact?

Investigators’ efforts to evaluate the relative costs of conducting surveys using the two sampling plans were only partially successful, primarily because of incomplete survey data. Survey results did not include a complete record of time spent by surveyors traveling between sampling sites, and there were other irregularities with time data.

While not conclusive, after investigators corrected as much as possible for this lack of data, the results of this project suggest that while the 14-foot presence-absence surveys required less than half the time to conduct, they were less precise than the 225-foot surveys at quantifying infestation density.

What’s Next?

A Mn/DOT report to be published in October 2009 will include data collected from 225-foot and 14-foot sampling surveys conducted in 2008. Investigators hope to use this data to better quantify the precision of the 14-foot survey results, further test the Kono and Sugino model, and develop conclusive results as to which sampling plan is more efficient and cost-effective, within a specified sampling precision, for assessing weed population distribution in highway rights-of-way.

This Technical Summary pertains to Report 2009-10, “Implementation of Methodology for Weed Management Practices,” published February 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200910.pdf>.

The research being implemented via this project is Report 2007-42, “Management Practices for Weed Control in Roadway Rights-of-Way,” published October 2007. This report can be accessed at <http://www.lrrb.org/PDF/200742.pdf>.



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PROJECT COST:

\$50,663



To assess the cost of fish passage culvert designs, work plans were obtained from 15 installations (indicated by circles) in the state.



RESEARCH
SERVICES SECTION

Cost Analysis of Fish-Friendly Culvert Designs

What Was the Need?

Because of Minnesota's abundance of lakes, rivers and streams, there are thousands of culverts to allow these waters to flow beneath the roads that cross over them. Many objectives are considered when designing modern culvert projects, including upstream and downstream flooding impacts, maintaining or enhancing wetland functions, flood plain management, public safety and cost. An additional increasing concern has been that in some streams, culvert designs present obstacles for migrating fish: shallow water, turbulence, high flow velocity and perched inlets (culvert openings that are too high for the fish to enter). One study showed that 67 percent of the culverts in the Pine-Popple region of Wisconsin either partially or totally blocked the passage of fish.

Recent designs that focus on matching the culvert to the natural characteristics of the stream are currently being implemented in certain areas of Minnesota where fish passage is a concern. County engineers needed more information about the necessity, function and additional costs associated with these culverts. Most research in this area has focused on salmon and trout in the Western United States.

What Was Our Goal?

The objectives of this project were to study concerns about fish passage as they apply to Minnesota fish species and environments, gather information about current culvert design practices in the state, and produce a cost analysis of alternative culvert designs.

What Did We Do?

Researchers first reviewed fish passage research from the East and West Coast regions. Although there were some differences with regard to fish species, landscape and water movement characteristics, the problems causing the blockage of fish passage were similar enough to warrant the evaluation of these studies.

To produce a statewide picture of current culvert design and installation practices, researchers administered surveys and conducted phone interviews with county engineers and Department of Natural Resources personnel. They additionally reviewed statewide general and county construction permits for evidence of culvert usage practices.

Investigators analyzed the cost differential between a stream simulation culvert design and traditional culvert placement by re-engineering 12 culverts at 12 separate Minnesota stream crossings and determining the cost differential for installing the stream simulation design. Stream simulation buries the culvert approximately 1 foot underground; this gives water moving through the culvert some characteristics of natural water movement.

In addition, researchers analyzed the costs of three strategies used as additions to in-place designs to facilitate fish passage:

- Baffles, which use panels inside the culvert to slow down water flow
- Roughened channels, which add rock and sediment to create diversity in flow rates and patterns
- Backwater weirs, which are dams constructed to hold water upstream so as to elevate the water level and eliminate a perched culvert, or downstream to slow water flow

continued

“This project effectively demonstrated that fish passage culvert designs are not excessively more expensive than traditional designs, especially when compared to overall construction costs.”

–John Nieber,
Professor, University of
Minnesota Department
of Bioproducts and
Biosystems Engineering

“There is still concern about the cost of the stream simulation designs. More study is needed to determine if these designs actually improve fish passage with the fish and environments we have in our state.”

–Alan Forsberg,
Public Works Director,
Blue Earth County

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Erosion has created a dropoff distance between the water and culvert opening. Salmon swimming upstream would not be able to enter these culverts and continue their passage.

What Did We Learn?

Researchers found that while species of fish and the stream environments are quite different between coastal regions and Minnesota, there is sufficient potential to warrant studying coastal techniques for possible application here.

The interviews, surveys and permit reviews revealed that there is no regional or state-wide ranking or prioritization system for fish passage in the state, and that prioritizing culvert design for fish passage is done on a case-by-case basis, primarily depending on potential benefits to fish resources. Alternative fish passage designs were found to be used less than 30 percent of the time, and there was a relatively low level of expertise among both agency and DNR staff regarding fish passage design and where it should be applied. Researchers did determine, however, that some aspects of various alternative designs are being implemented in different areas of the state.

When culverts designed using modern methods were compared to those using alternative fish passage designs, they were found to be generally similar; however, the cost of setting the bottoms of the fish passage designs into the stream bed and sometimes wider spans resulted in an average cost increase of 10 percent. No decrease in maintenance or erosion was documented with the fish passage designs.

The three existing culvert additions studied—baffles, roughened channels and backwater weirs—averaged between 10 percent and 15 percent of the culvert cost.

What's Next?

Three follow-up studies are currently being pursued to address these questions:

- What is the actual impact on fish populations and aquatic life by conventional culvert designs?
- What ecological effects and maintenance costs would result with stream simulation design?
- Does Minnesota need a statewide guidance document addressing regional fish concerns and local geographical conditions for the purpose of prioritizing and suggesting a best fit culvert design?

The Minnesota Local Technical Assistance Program offered [a workshop on culvert design, installation and maintenance](#) that included the findings of this study.

This Technical Summary pertains to the LRRB-produced Report 2009-20, “Cost Analysis of Alternative Culvert Installation Practices in Minnesota,” published June 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200920.pdf>. For more information about the follow-up studies mentioned, please contact research@state.mn.us.



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PROJECT COST:

\$170,055



This truck laying down fly ash on RPM will be followed by a road reclaimer with tines for blending them together.



RESEARCH
SERVICES SECTION

Using Fly Ash to Improve Recycled Pavement Foundations

What Was the Need?

To minimize costs and environmental impact, Minnesota often recycles existing pavements during road reconstruction using methods like full depth reclamation where the hot-mix asphalt pavement is pulverized with a portion of the aggregate base to create a blend of recycled pavement material. This serves as the new pavement foundation and is compacted and overlaid with fresh HMA. Similarly, when an unpaved road with a gravel surface is upgraded to a paved road, the existing road surface gravel can be blended with recycled power plant ash and then compacted to form a new base layer.

These recycled materials may contain aged asphalt binder, fines and other elements that affect the strength and stiffness of the pavement base. To address this issue, another recycled material called fly ash—a byproduct of coal-burning power plants that is self-cementing when it reacts with water—can be blended with RPM and RSG to increase their strength and stiffness. The use of these stabilized materials in Minnesota, referred to as SRPM and SRSG, is still relatively new, and the Local Road Research Board has been involved in ongoing research to establish their performance, required design specifications and environmental impact.

What Was Our Goal?

The goals of this study were to:

- Develop a practical method to design local roadways using SRPM and SRSG as base layers by establishing their gravel equivalency, or the thickness of these materials needed to achieve a strength and stiffness equivalent to traditional sand and gravel.
- Evaluate the performance of SRPM and SRSG in two field projects.
- Assess the environmental impacts of these materials using both field data and predictive computer modeling applied to laboratory data.

What Did We Do?

Researchers began by collecting samples of RPM and RSG from two demonstration projects in Minnesota and mixing some of these with Class C fly ash to create samples of SRPM and SRSG. They evaluated the strength and stiffness of all samples with resilient modulus and California bearing ratio tests before and after a series of freeze-thaw cycles.

Researchers then monitored pavement performance at the two field sites from which they had collected RPM and RSG. These projects had used fly ash-stabilized bases, and researchers instrumented the resulting SRPM and SRSG to measure temperature, frost depth and water content. They also made annual surveys of in situ pavement modulus using a falling weight deflectometer, and recorded signs of rutting and other distress.

Finally, researchers evaluated the environmental impact of these materials by placing pan lysimeters beneath field project roadways to collect and test water percolating from base layers for chemicals that might have leached from the fly ash. Researchers also tested SRPM and SRSG field samples in the laboratory for the same chemicals and applied computer modeling to this data to predict groundwater impact.

What Did We Learn?

Results showed that fly ash-stabilized bases are strong, durable and cost-effective. The resilient modulus of SRPM and SRSG increased significantly with fly ash content. To account for this increase, researchers developed a design procedure for selecting SRPM

continued

“This project gave us a way to quantify the performance of recycled fly ash during design by providing simple conversions of required thicknesses from Class 5 aggregate to fly ash-stabilized recycled materials.”

—John Siekmeier,
Mn/DOT Senior Research
Engineer

“Fly ash stabilization has proven itself to be capable of providing a durable foundation for construction equipment and local traffic before and during paving, and shows promise for providing long-term pavement support.”

—Tuncer Edil,
Professor, University of
Wisconsin—Madison
Department of Civil and
Environmental
Engineering

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Researchers collected samples of fly ash to mix in the laboratory with samples of RPM and RSG; these stabilized samples were tested for stiffness and strength over five freeze-thaw cycles.

and SRSR base thicknesses that achieve the same structural capacity as a conventional Class 5 base course. The effects of freeze-thaw cycles were expected to be negligible once offset by increased stiffness caused by curing.

Falling weight deflectometer field data confirmed the efficacy of SRPM and SRSR, with moduli for one site remaining stable over four years despite several seasons of freezing and thawing. On the other site, SRSR resilient moduli decreased slightly during the first year but remained stable thereafter.

Environmental monitoring showed that in general contaminant levels were below limits permitted by U.S. Environmental Protection Agency and Minnesota regulations. In some cases, concentrations measured in base percolation (but not in groundwater) modestly exceeded these standards. However, computer modeling showed that under most conditions these concentrations are expected to decrease with time and become diluted with distance from the roadway, yielding groundwater that meets environmental standards.

What's Next?

Researchers recommend periodic monitoring of field sites for five to 10 years to assess the long-term performance of SRPM and SRSR. They recommend additional environmental research to establish the safety of these materials as well as specifications limiting chemical concentrations in fly ash.

The LRRB has just issued another [report on the strength and environmental impact of recycled materials](#). Previously the LRRB demonstrated [ash utilization in low-volume roads](#) and developed a [screening tool to assess fly ash risks](#). Further fly ash environmental evaluation [has been proposed](#). Minnesota is also involved in an effort to investigate whether [using high carbon fly ash to stabilize recycled pavement materials can help reduce carbon dioxide emissions](#).

This Technical Summary pertains to the LRRB-produced Report 2009-27, “Use of Fly Ash for Reconstruction of Bituminous Roads,” published August 2009. The full report and appendices can be accessed at <http://www.lrrb.org/PDF/200927.pdf> and <http://www.lrrb.org/PDF/200927A.pdf>.

Full reports for the related LRRB studies referred to in this report can be found at <http://www.lrrb.org/PDF/200932.pdf>, <http://www.lrrb.org/PDF/200712.pdf> and <http://lrrb.org/PDF/200503.pdf>. Research Services is preparing an “Innovation Update” on fly ash; please contact research@state.mn.us for this document.



RESEARCH SERVICES SECTION

TECHNICAL SUMMARY

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Principal Investigator:

John Nieber, University of Minnesota

PROJECT COST:

\$15,800



Canada thistle, the most invasive noxious weed in Minnesota, quickly replaces native plants and is very difficult to control because of its extensive root systems.

Putting Research into Practice: Reducing the Costs of Noxious Weed Management

What Was the Need?

Minnesota transportation agencies are required by law to manage certain noxious weeds along highways, either by eradicating them or destroying as much aboveground growth as possible to prevent maturation and propagation. Noxious weeds are a threat to natural ecosystems, crops and livestock; they make pavement and stormwater maintenance more difficult; and they can threaten driver safety by obscuring road signs.

To control weeds, agencies use a combination of mowing and herbicides, which are costly and can adversely affect the environment. Consequently, it is important to carefully customize weed management practices to fit the severity of infestations. However, determining the location and distribution of weeds over the large areas comprising highway rights of way can itself be costly and time-consuming. Research was needed to develop more efficient methods for surveying weed infestations.

What Was Our Goal?

This project is Phase II of an implementation effort to increase the precision of noxious weed infestation surveys and reduce the time required to conduct them by comparing the efficiencies of sampling plans developed during the implemented project: one measuring weed population density (area infested per unit length of highway) over 100 225-foot segments, and the other potentially less labor-intensive method measuring weed population distribution (presence or absence of weeds) over 150 14-foot segments.

The goal of Phase II of this implementation was to verify the key findings of [Phase I](#) by supplementing gaps in its data with additional field surveys, data processing and statistical analysis.

What Did We Implement?

This project is the second phase of an implementation of an earlier Mn/DOT study, "Management Practices for Weed Control in Roadway Rights-of-Way" (2007-42), published October 2007. This study compared the accuracy and efficiency of two weed survey methods used during 2004 and 2005:

- The method used from 2000 to 2004, which involved evaluation of infestations over 3-mile-long segments and extrapolation to the district as a whole.
- A new method that used greater numbers of smaller, 1/4-mile-long segments.

The study showed that the older method was less precise, and researchers predicted via statistical analysis that sampling precision would be further improved by using even smaller segments of 225 feet or less, which were evaluated in this implementation.

How Did We Do It?

In 2008, Mn/DOT District 4 personnel conducted field surveys in the same areas that had been previously surveyed in 2004, 2005 and 2007, using Global Positioning System devices to map the population distribution of 13 noxious weed species in highway rights of way. Surveyors mapped the population densities for these sites in 225-foot-long segments, recording patch area, location, landscape position, and the number and species of weeds within each segment. They also mapped these sites in 14-foot-long segments for population distribution, or presence-absence data, which measures which segments had at least one weed and which segments had none.

continued

“These studies laid the groundwork for a systematic approach to weed management in Minnesota. To measure the effectiveness of its efforts and avoid wasting resources, Mn/DOT must have a method for accurately quantifying weed infestations.”

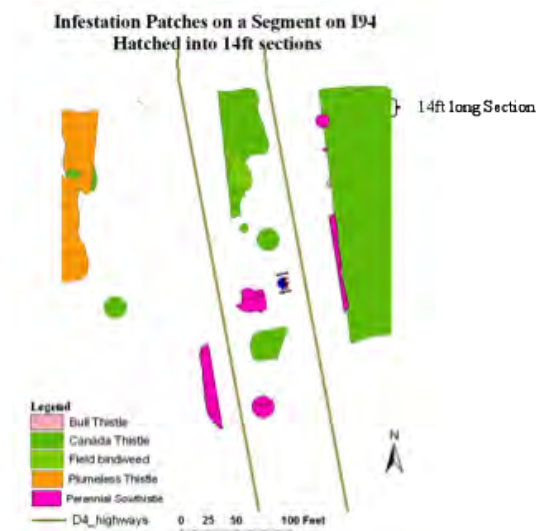
–Paul Walvatne,
Supervisor, Mn/DOT
Roadside Vegetation
Management Unit

“Developing better weed survey methods has given us a more cost-effective way to determine when and where it is better to spray, mow or establish diverse native plant communities to outcompete weeds in their niches.”

–John Nieber,
Professor, University of
Minnesota Department
of Bioproducts and
Biosystems Engineering

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This 225-foot segment mapping infestation by weed species has been divided into 14-foot subsections.

Investigators then used a mathematical model calibrated in Phase I to extrapolate population densities from presence-absence data of 14-foot-long segments and to measure their accuracy by comparing calculated densities to those measured using 225-foot-long segments. They also compared the costs of each sampling plan by analyzing the amount of time it took weed inspectors to inspect each sampling segment, travel between segments, travel to and from sites and their offices, and to complete other tasks such as servicing equipment and taking breaks.

What Was the Impact?

Results showed that using 14-foot segments required significantly less effort than using 225-foot segments. It took inspectors less time both to inspect the 14-foot segments and to travel between them. However, the study also confirmed the results of Phase I showing that the use of 14-foot segments was less precise than the use of 225-foot surveys, and too imprecise to be used to quantify infestation density. Nonetheless, this 14-foot method is an effective and less costly way to detect new weed species or early invaders in highway rights of way.

What's Next?

The 225-foot segment surveys developed in this series of studies have been implemented successfully in Mn/DOT District 4, and other districts are planning implementation. These surveys save time and effort in quantifying weed infestations, and are part of Mn/DOT's ongoing development of an integrated systems approach to weed management that targets the right combinations of weed control strategies to the time of year and type and severity of infestation.

Researchers recommend the further development of systems approaches, especially for the control of Canada thistle, which is the most prevalent and problematic noxious weed in Minnesota. They also recommend closer analysis of the 14-foot segments examined in this study, and will continue to process study data in an ongoing effort to develop more cost-effective weed survey methodologies.

This Technical Summary pertains to the LRRB-produced Report 2009-28, "Implementation of Methodology for Weed Management Practices—Phase II," published September 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200928.pdf>. The report for Phase I of this implementation effort can be accessed at <http://www.lrrb.org/PDF/200910.pdf>.

The research being implemented via this project is Report 2007-42, "Management Practices for Weed Control in Roadway Rights-of-Way," published October 2007. This report can be accessed at <http://www.lrrb.org/PDF/200742.pdf>.



TECHNICAL SUMMARY

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Principal Investigators:

Henry Liu, University of Minnesota
Panos Michalopoulos, University of Minnesota

PROJECT COST:

\$70,000



Traffic monitoring received the worst possible grade in this report card issued by the National Transportation Operations Coalition.



RESEARCH SERVICES SECTION

Real-Time Arterial Performance Monitoring Using Traffic Data from Existing Signal Systems

What Was the Need?

Reducing traffic congestion, and the costs and quality-of-life issues that come with it, has been identified as a major focus area for Minnesota's transportation agencies. One promising and relatively inexpensive avenue for responding to this challenge is improving the operational efficiency of traffic signals, as this allows improved use of existing roadways without additional construction. Though traffic signals have been shown to play a critical role in managing urban traffic networks, there is room for improvement in how the signals are managed.

Managing traffic signals requires data. While most signal systems are capable of generating the data needed to manage signal timing, data collection and calculation of performance measures such as delay and travel time must be done manually. Data collection accounts for over 50 percent of the estimated \$2,500 to \$5,500 cost to retune traffic signals for a single intersection. Mn/DOT and Minnesota's city and county public works agencies needed a more cost-effective way to gather the data required to better manage urban traffic network signal systems.

What Was Our Goal?

The goal of this project was to develop and test a real-time performance measurement system to automatically collect traffic signal data on arterial road networks. This would involve developing a set of mathematical models that would be applied to the collected data to estimate performance measures such as queue length, delay, travel time and number of stops. This information could then be used by engineers to reset timing schedules for individual traffic signals.

What Did We Do?

Researchers reviewed existing literature and then developed a system architecture and data collection techniques that constitute the SMART-SIGNAL (Systematic Monitoring of Arterial Road Traffic Signals) system. SMART-SIGNAL collects and archives high-resolution traffic signal data and automatically generates real-time performance measures. The system uses advance detectors that record vehicles as they move through the intersection, and stop-line detectors that record through-movement and left-turning vehicles. A computer in the signal controller cabinet records the data collected without affecting the usual operation of the signal controller.

In February 2007, with the assistance of Hennepin County Public Works, researchers installed SMART-SIGNAL on an 11-intersection arterial corridor along France Avenue in Hennepin County. The system continuously collected and archived data during the study period. The system collected two primary pieces of data: a detector event, which indicates that a vehicle is arriving, and a signal phase change event that is recorded whenever the traffic signal changes.

This real-time information was sent continuously via a digital subscriber line to a database at the University of Minnesota's Traffic Lab. Using the raw data, performance measures were automatically generated in the database by applying two mathematical models developed in the study:

- A time-dependent queue length estimation model that can handle long queues under both low-volume and congested conditions.

continued

“SMART-SIGNAL can provide near real-time information about queue lengths and travel times, allowing staff to make manual adjustments to preprogrammed timing plans that will have an immediate effect on reducing congestion.”

–Eric Drager,
Traffic Operations
Engineer, Hennepin
County Public Works

“The new algorithm to estimate queue length represents a breakthrough. Traditional models can’t capture queues that extend beyond the advance detector.”

–Henry Liu,
Assistant Professor,
University of Minnesota
Department of Civil
Engineering

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SMART-SIGNAL's data collection devices installed in a France Avenue signal controller cabinet received data from vehicle detection units and the traffic signal controller.

- An arterial travel time model that uses data from existing signal controllers and vehicle detection systems to mimic typical travel behavior in order to determine the total time from a given origin to a given destination. This traces virtual probe vehicles from origin to destination.

What Did We Learn?

Researchers used performance measures generated by SMART-SIGNAL to examine the benefits of new signal timing plans implemented by the Hennepin County Transportation Department along the France Avenue corridor. An examination of data collected before and after implementation of these plans demonstrated improvements in performance measures such as travel time, delay, number of stops, and level of service under the new plans. Hennepin County reports that SMART-SIGNAL's performance data confirmed the results of an engineering consulting firm's signal timing study of the corridor. SMART-SIGNAL's estimated arterial travel times were also found to be highly consistent with real travel times recorded along the France Avenue corridor.

What's Next?

Hennepin County has removed the SMART-SIGNAL prototype from the France Avenue corridor but is funding research to install a retooled prototype near Southdale.

This project is regarded as a definite success and received the 2009 University of Minnesota Center for Transportation Studies Research Partnership Award. SMART-SIGNAL development continues, with additional research funded by the university's Intelligent Transportation Systems Institute under way to automate signal retiming and develop predictive models to determine performance measures for signalized arterials.

Mn/DOT has also initiated additional research to continue development of the eventual end-user product by installing SMART-SIGNAL at 15 intersections along Trunk Highway 13. This new research is focused on fine-tuning SMART-SIGNAL's data collection equipment to prepare for the next generation of signal controller cabinets, and creating a Web interface for end users.

This Technical Summary pertains to the LRRB-produced Report 2009-01, "Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems," published December 2008. The full report can be accessed at <http://www.lrrb.org/PDF/200901.pdf>.



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Principal Investigator:

Henry Liu, University of Minnesota

PROJECT COST:

\$70,000



Investigators conducted lab simulations using a personal computer, controller cabinet and signal controller.

Integrating Platoon-Priority Signal Control with Advance Warning Flashers

What Was the Need?

When intersections are located fairly close to one another, vehicles tend to arrive in batches and can be effectively managed with coordinated signal control to keep vehicles moving along the major approach. In contrast, isolated high-speed rural or suburban signal-controlled intersections often operate poorly during peak times. For these intersections, advance detectors fail to recognize an approaching batch—or platoon—of vehicles, and vehicles on the major approach can experience increased delays while waiting for relatively few vehicles on the minor approach.

Two strategies have been used to provide for smooth progression of platoons along transportation corridors, but there was little literature on how these methods might be integrated:

- Platoon-priority signal control systems identify the arrival of a platoon of vehicles and coordinate signal timing between a series of intersections.
- Advance warning flashers warn motorists on high-speed approaches that the signal phase will be turning yellow.

Conventional AWF configurations add a fixed interval (7 to 8 seconds) at the end of a green phase, during which the flashers activate. This tends to increase delays on the minor approach, and these installations also leave out the “dilemma-zone protection” of a typical high-speed intersection, which involves detectors that extend the green light phase if a vehicle is at the point where it could not safely stop were the light to change. As these detectors are already present in platoon-priority signal control systems, integrating them with AWF seemed a promising method of increasing the efficiency of high-speed isolated intersections while retaining dilemma-zone protection.

What Was Our Goal?

Investigators aimed to develop an integrated signal control system that would:

- Detect in real time long platoons approaching the intersection and extend the green light to allow these vehicles to pass without causing excessive delays to the small number of vehicles on the minor approach.
- Use both platoon identification and AWF to provide a better starting time for warning flashers based on traffic conditions that leaves in place dilemma-zone protection.

What Did We Do?

Investigators developed two algorithms to test in a lab simulation:

- Platoon-priority algorithm: This two-stage algorithm keeps track of vehicle arrivals at the intersection to detect a platoon. Each additional vehicle following the platoon is evaluated to determine where to provide platoon priority to the vehicle.
- AWF algorithm: This algorithm uses advance detector data and signal controller status in real time to predict when the green phase will terminate due to an excessive interval in between vehicles arriving on the green. The arrival time of each vehicle at the dilemma-zone detector is used to place a hold on the phase to safely clear the vehicle from the dilemma zone.

Investigators used the intersection of Minnesota Highway 55 and Argenta Trail in Inver Grove Heights, Minnesota—a high-speed, signalized isolated intersection with major and

continued

“The next step is to field-test the platoon-priority strategy. Rural high-speed intersections are good candidates for testing if they have high volumes of through traffic on the major approach and limited traffic on the side street.”

—Susan Zarling,
Mn/DOT Traffic Electrical
Systems Engineer

“We made the cabinet-in-the-loop simulation as realistic as possible by integrating the algorithms in the testing architecture. Vehicle arrivals to the testing intersection were simulated by a computer program, and the traffic light was operated using the controller cabinet.”

—Henry Liu,
Assistant Professor,
University of Minnesota
Department of Civil
Engineering

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Traffic data gathered using detectors at this high-speed, signalized isolated intersection was used in simulations of different signal control systems in the lab.

minor approaches—to gather vehicle speed distribution data for the simulation. Current detection equipment, located approximately 300 to 400 feet from the intersection, was used with a new advance loop detector installed 1,000 to 1,250 feet upstream of the intersection. Together, the two detectors allowed investigators to identify platoons based on vehicle speed and the time difference between vehicles.

To test the integrated system, investigators applied the algorithms in a cabinet-in-the-loop system consisting of a personal computer, an actual signal controller and a controller cabinet. The integrated system software that applies the algorithms receives advance detector information such as vehicle type and speed from data gathered in the field. It also receives phase detector status and signal status from the cabinet and, when required, sends controller override input calls to the cabinet.

What Did We Learn?

Performance measures were calculated to determine reductions in cumulative delay and number of stops when comparing the platoon-priority model against operations in normal signal control mode. Investigators found a more than 50 percent reduction in delays and stops for the major approach with the platoon-priority model, and overall intersection delays and stops were reduced by 20 percent.

Advance detection at 1,250 feet provided optimal performance, and with advance detection at this distance and an approach speed of 65 mph, the system was able to provide 6 to 7 seconds advance warning of end-of-green in a majority of the cases. However, the system was not as effective at intersections with a high percentage of platoons making turns.

What's Next?

Mn/DOT is considering locations to field-test the integrated system. Good candidates for field tests are rural high-speed intersections that experience vehicle platoons, limited turning movements on major approaches and light traffic on side streets. Cabinet-in-the-loop lab testing of the proposed intersections will precede any testing in the field.

This Technical Summary pertains to Report 2009-23, “Development of a Platoon-Priority Control Strategy with/out Smart Advance Warning Flashers for Isolated Intersections with High-Speed Approaches,” published July 2009. The full report can be accessed at <http://www.lrrb.org/PDF/200923.pdf>.



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Minnesota Local Road Research Board: www.lrrb.org



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RESEARCH SERVICES

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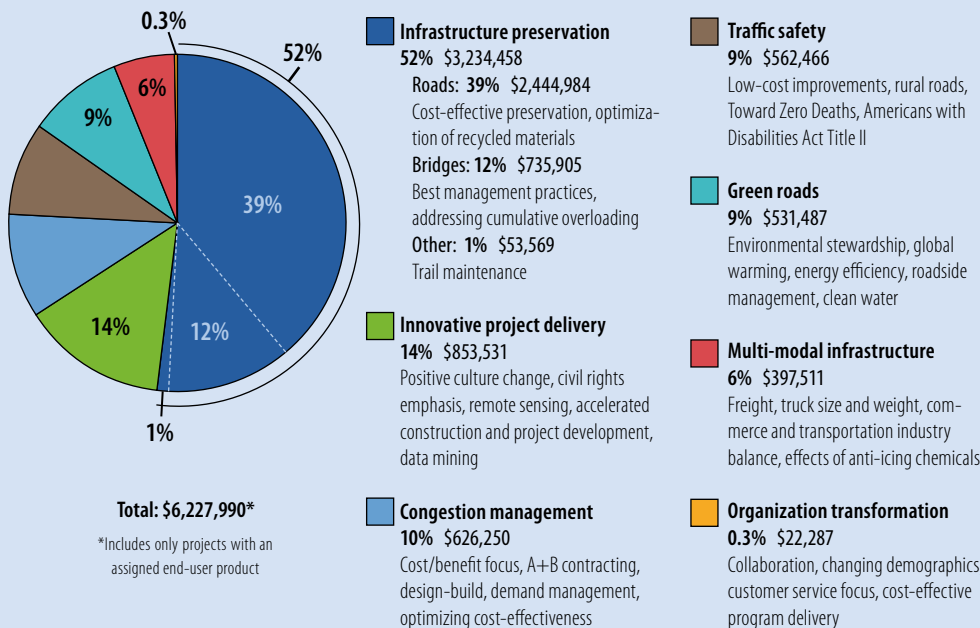
2009 At-A-Glance

This publication provides a guide to the Minnesota Department of Transportation's 2009 research activities. It includes:

- Lists of reports completed in 2009 and other completed projects that did not result in a report
- A graphical account of progress on all 2009 active research contracts as of November 2009
- A list of multi-state pooled fund projects that Mn/DOT leads or participates in
- Key research and library statistics
- Breakdowns of research spending by funding program and by the strategic research areas that will continue to guide Mn/DOT research over the coming years

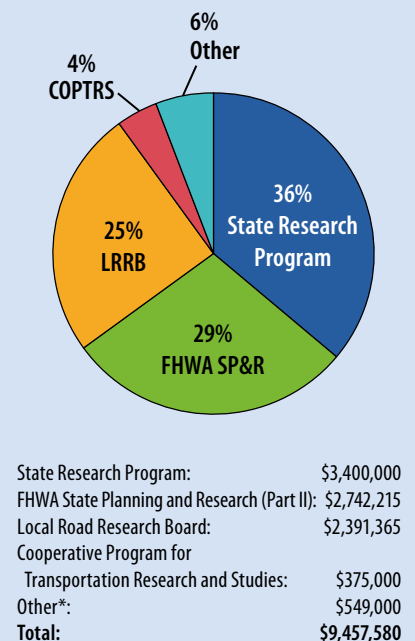
Mission: Mn/DOT Research Services supports measurable improvements in Minnesota's transportation system by meeting the innovation and information needs of transportation practitioners and the transportation community.

FY 2009 Funding Distribution by Mn/DOT Strategic Research Area



Addressed through progress in other focus areas with communication of results:
Responding to customers and stakeholders
 Building public confidence, transparency, Hear Every Voice, ADA, gas price impacts, legislative decision making, innovative contracting and financing

FY 2009 Funds Available



*Includes contributions from other Mn/DOT offices (Maintenance, Traffic, Materials, Investment Management and Policy Analysis, Research & Innovation) and districts along with the Twin Cities Metropolitan Council.

Completed Research Reports and Implementation Products, January through October 2009

FUNDING SOURCE KEY

LRRB	Local Road Research Board
MAT	Office of Materials
OM	Office of Maintenance
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 2009 Annual Report or at www.dot.state.mn.us/research. "N/A" in the cost column indicates that this report was funded by administrative sources or as part of a project already listed on the 2009 Active Contracts list.

Funding Source	Cost	Report Number	Report Title	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
LRRB	\$186,735	2009-08	INV 830: Evaluating Roadway Subsurface Drainage Practices	University of Minnesota	John Nieber, Gary Sands	Stephen Schneider, Andrew Eller	Nelson Cruz	X
LRRB	\$161,553	2009-27	INV 847: Use of Fly Ash for Reconstruction of Bituminous Roads	University of Minnesota	Paul Bloom, Tuncer Edil	John Siekmeier	Nelson Cruz	X
LRRB	\$153,875	2009-32	INV 846: Hydraulic, Mechanical and Leaching Characteristics of Recycled Materials	University of Minnesota	Satish Gupta	John Siekmeier	Nelson Cruz	X
LRRB	\$118,908	2009-03	INV 848: Warning Efficacy of Active Versus Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Crosswalks	University of Minnesota	Thomas Smith, Nikos Papanikolopoulos	Deb Bloom	Dan Warzala	X
LRRB	\$105,000	2009-21	INV 850: Mechanistic Modeling of Unbound Granular Materials	University of Minnesota	Kimberly Hill, Lev Khazanovich	Lee Amundson	Nelson Cruz	X
LRRB	\$75,000	2009-04	INV 842: Best Practices for Dust Control on Aggregate Roads	Mn/DOT Office of Materials	Eddie Johnson	John McDonald	Shirlee Sherkow	X
LRRB	\$71,638	2009-17	INV 852: Subsurface Drainage Manual for Pavements in Minnesota	University of Minnesota	John Nieber	Dan Sauve	Alan Rindels	X
LRRB	\$71,050	2009-18	INV 861: Preventive Maintenance Best Management Practices of Hot Mix Asphalt Pavements	Mn/DOT Office of Materials	Thomas Wood, Erland Lukanen	Tim Stahl	Shirlee Sherkow	X
LRRB	\$70,007	2009RIC11	INV 645: Implementation of Pavement Management in Minnesota	SRF Consulting Group, Inc.	Michael Marti	Richard Sanders	Clark Moe	X
LRRB	\$70,000	2009-01	INV 862: Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems	University of Minnesota	Henry Liu, Wenteng Ma, Xinkai Wu, Heng Hu	Eric Drager	Shirlee Sherkow	X
LRRB	\$60,561	2009-12	INV 860: Using the Dynamic Cone Penetrometer and Light Weight Deflectometer for Construction Quality Assurance	Mn/DOT Office of Materials	John Siekmeier	Merle Earley	Shirlee Sherkow	X
LRRB	\$57,872	2009-02	INV 773-3: Oak Grove Tire Shreds Project: Tire Shreds Below the Seasonal Groundwater Table, Years 2006-2008	Mn/DOT Office of Materials	Robert Edstrom	Ronald Mortensen	Dan Warzala	X
LRRB	\$53,569	2009-25	INV 876: Preventive Maintenance for Recreational Trails	Mn/DOT Office of Materials	Roger Olson, Erland Lukanen	Duane Schwartz	Shirlee Sherkow	X
LRRB	\$51,747	2009RIC12	INV 645: Stormwater Maintenance BMP Resource Guide	SRF Consulting Group, Inc.	Michael Marti	Mark Maloney	Clark Moe	X
LRRB	\$50,663	2009-20	INV 870: Cost Analysis of Alternative Culvert Installation Practices in Minnesota	University of Minnesota	John Nieber, Bruce Wilson	Alan Forsberg, Susan Miller	Alan Rindels	X
LRRB	\$30,789	2009-15	INV 826: Best Practices for RAP Use Based on Field Performance	Mn/DOT Office of Materials	Eddie Johnson, Jim McGraw	John Brunkhorst, David Linell	Dan Warzala	X
LRRB	\$25,565	2009RIC02	INV 645: Innovative Contracting Methods	SRF Consulting Group, Inc.	Michael Marti	Tom Behm	Clark Moe	X
LRRB	\$11,000	2009-09	INV 873: Recycled Pavements Using Foamed Asphalt in Minnesota	Mn/DOT Office of Materials	Roger Olson, Andrew Eller	Mark Maloney	Sandy McCully	X
LRRB	N/A	2009-19	INV 879: MnROAD Cell 64 Pervious Concrete: Third Year Performance Report	Mn/DOT Office of Materials	Ryan Rohne, Bernard Izevbekhai	N/A	N/A	
LRRB/SRP	\$292,385	2009-06	INV 815: Implementation of the MEPDG for New and Rehabilitated Pavement Structures for Design of Concrete and Asphalt Pavements in Minnesota	University of Minnesota	Lev Khazanovich, Mihai Marasteanu	Gerard Geib	Dan Warzala	X
LRRB/SRP	\$92,397	2009-05	INV 831: Investigation of Stripping in Minnesota Class 7 (RAP) and Full-Depth Reclamation Base Materials	North Dakota State University	Magdy Abdelrahman	Tim Andersen	Nelson Cruz	X

Completed Research Reports and Implementation Products, cont.

Funding Source	Cost	Report Number	Report Title	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
LRRB/SRP	\$75,000	2009-13	INV 858: Crack and Concrete Deck Sealant Performance	University of Minnesota	Arturo Schultz, Cathy French	Jim Lilly	Nelson Cruz	X
LRRB/SRP	N/A	TRS0901	INV 881: Methods and Practices for Control of Canada Thistle	Darlene Gorrill	Darlene Gorrill	Linda Taylor	Sandy McCully	
SRP	\$184,000	2009-24	Access to Destinations: Application of Accessibility Measures for Non-Auto Travel Modes	University of Minnesota	Robert Johns, Kevin Krizek	Lisa Austin	Linda Taylor	X
SRP	\$153,900	2009-37	Developing a Resistance Factor for Mn/DOT's Pile Driving Formula	Minnesota State University, Mankato	Aaron Budge	Gary Peterson	Nelson Cruz	X
SRP	—	2009-38	Development of a Resistance Factor for Mn/DOT's Pile Driving Formula and Study of Pile Setup Evaluation Methods: Predicting Magnitude and Rate of Pile Setup	Minnesota State University, Mankato	Aaron Budge	Gordy Pehrson	Nelson Cruz	
SRP	\$143,160	2009-29	Bridge Health Monitoring and Inspections System	University of Minnesota	Arturo Schulz, Carol Shield	Todd Niemann	Shirlee Sherkow	X
SRP	\$91,388	2009-33	Development of Data Warehouse and Applications for Continuous Vehicle Class and Weigh-in-Motion Data	University of Minnesota - Duluth	Taek Kwon	Benjamin Timerson	Nelson Cruz	X
SRP	\$72,637	2009-16	The Economic Impact of Upgrading Roads	University of Minnesota	David Levinson	Rabinder Bains, Ronald Lambert	Alan Rindels	X
SRP	\$70,000	2009-23	Development of a Platoon-Priority Control Strategy with/out Smart Advance Warning Flashers for Isolated Intersections with High-Speed Approaches	University of Minnesota	Henry Liu	Susan Zarling	Shirlee Sherkow	X
SRP	\$65,000	2009-07	Advanced Acquisition of Right-of-Way: Best Practices and Corridor Case Studies	University of Minnesota	Adeel Lari, Robert Brown	Rabinder Bains	Dan Warzala	X
SRP	\$51,832	2009-11	Post-Construction Evaluation of Forecast Accuracy	University of Minnesota	David Levinson	Gene Hicks	Shirlee Sherkow	X
SRP	\$47,628	HE365M6	From Footpaths to Freeways: A Survey of Roads and Highways in Minnesota	University of Minnesota	Gina Baas	Sue Lodahl	Cory Johnson	
SRP/OM	\$20,270	2009-10	Implementation of Methodology for Weed Management Practices	University of Minnesota	John Nieber, Donald Wyse	Paul Walvatne	Shirlee Sherkow	X
SRP	\$9,023	TRS0803	Planned and Unplanned Disruptions to Transportation Networks	University of Minnesota	David Levinson, Shanjiang Zhu	Linda Taylor	Alan Rindels	
SRP	\$6,117	TRS0903	Issues of Concern Related to Underground Infiltration Systems for Stormwater Management & Treatment	Bonestroo, Rosene, Anderlik & Assoc., Inc.	Randy Neprash	Paul Kauppi	Shirlee Sherkow	
SRP	N/A	2009-31	Sixty-Year Design Concrete Pavement-Performance Model Development: MnROAD Cell 53 Construction Report	Mn/DOT Office of Materials	Ryan Rohne	N/A	N/A	
SRP/SP&R	\$35,630	N/A (Project 2007-084)	Implementation of Steel Bridge Maintenance Planning	University of Minnesota	Arturo Schulz	Jim Pierce	Bruce Holdhusen	X
SRP/SP&R	N/A	TRS0902	Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice	CTC & Associates LLC	Pat Casey, Chris Kline	Linda Taylor	Jake Akervik	
SP&R/MAT	\$425,000	2009-14	Implementation of Intelligent Compaction Performance Based Specifications in Minnesota	Iowa State University	David White	John Siekmeier	Clark Moe	X
SP&R	\$84,457	2009-35	Procedures to Use and Manage IC Data in Real Time	CNA Consulting Engineers, Inc.	Lee D. Petersen	Rebecca Embacher, Tim Andersen	Clark Moe	X
SP&R	N/A	2009-22	2008 MnROAD Phase II Construction Report	Mn/DOT Office of Materials	Ann Johnson, Tim Clyne, Ben Worel	N/A	N/A	
SP&R	N/A	2009-26	Demonstration of Concrete Maturity Test Process on the TH-694/TH-35E Interchange—Unweave the Weave	Mn/DOT Office of Materials	Bernard Izevbekhai	N/A	N/A	
SP&R	N/A	2009-30	Ultrathin Bonded Wearing Course Performance Update, Minnesota	Mn/DOT Office of Materials	Ahmed Ali Ahmed	N/A	N/A	
OM	\$15,800	2009-28	Implementation of Methodology for Weed Management Practices—Phase II	University of Minnesota	John Nieber	Paul Walvatne	Shirlee Sherkow	X

Other Completed Contracts in 2009

Funding Source	Total Cost	Amount Paid	Project Number	Project Title	Performing Organization	Investigator	Tech Liaison	Admin Liaison	Contract Start Date	Contract End Date
LRRB	\$490,845	\$490,845	2008-015	INV 668: Local Technical Assistance Program (LTAP)	University of Minnesota	Jim Grothaus	Julie Skallman	Cory Johnson	6/10/2008	7/31/2009
LRRB	\$200,474	\$200,472	2006-080	MPR-6(013): Cadastral and Right of Way Data Exchange—R/W Sharing	Pro-West & Associates, Inc.	Annette Theroux	Mark Maloney, Rick Morey	Clark Moe	7/31/2007	7/31/2009
LRRB	\$112,500	\$112,500	2008-038 (wo107)	INV 869: TERRA Board Support—FY2009	University of Minnesota	Laurie McGinnis	Julie Skallman, Mark Maloney	Cory Johnson	8/1/2008	12/31/2009
LRRB	\$98,715	\$97,486	2006-042 (91415)	INV 845-1: Analysis of Highway Design and Geometric Effects on Crashes	CH2M Hill	Howard Preston	Glen Ellis	Shirlee Sherkow	7/19/2007	7/31/2009
LRRB	\$77,905	\$77,905	2006-039	INV 856: Investigation of In-Place Asphalt Film Thickness and Performance of Minnesota Hot Mix Asphalt Mixtures	University of Minnesota	Mihai Marasteanu	John Garrity	Dan Warzala	10/16/2006	6/30/2009
LRRB	\$54,495	\$35,003	2009-091 (2006-107 Task 13)	Guardrails RIC 2007-2008 RIC Task 13	SRF Consulting Group, Inc.	Michael Marti	Gary Danielson	Clark Moe	12/3/2008	10/31/2009
LRRB	\$1,729	\$1,729	2007-009 (93093)	Porous Asphalt Pavement Performance in Cold Weather Water Samples	Department of Health	N/A	Larry Matsumoto	Bruce Holdhusen	7/25/2008	7/1/2009
LRRB/SRP	\$50,000	\$50,000	2008-051 (89261 wo106)	RSS Report Publication Services, 2009	University of Minnesota	Gina Baas	Linda Taylor	Sandy McCully	7/23/2008	9/30/2009
SRP	\$23,052	\$23,052	2008-012 (89261 wo148)	Impacts of the Proximity to Transitway Stations on Commercial Property Values Partnership Agreement State and Met Council "Transitway Impacts Research Program"	University of Minnesota	Jason Cao	Robert Vockrodt	Dan Warzala	4/2/2009	10/31/2010
SRP/SP&R	\$209,000	\$171,200	2007-039 (91515)	MPR-6(005): Research Management System—Phase I	Archwing Innovations, LLC	Ryan Anderson	Cory Johnson	Cory Johnson	1/2/2008	4/30/2009
SRP/SP&R	\$140,690	\$139,283	2009-059 (90901)	Enterprise Program Management Consulting	Trissential	Steve Beise	Linda Taylor	Cory Johnson	8/6/2007	4/30/2009
SRP/SP&R	\$99,954	\$99,949	2007-075 (92707)	MPR-6(019): Technology Transfer Material Development—Phase II	CTC & Associates LLC	Patrick Casey	Cory Johnson	Jake Akervik	4/29/2008	1/31/2010
SRP/SP&R	\$23,130	\$23,130	2009-059 (93998)	MPR-6(003): Library Information Resources Update	Lowell Benson	Lowell Benson	James Byerly	Sheila Hatchell	3/30/2009	7/31/2009
SRP/SP&R	\$14,800	\$14,800	2008-070 (94977)	MPR-8(006): Maintenance Anti-Icing Study (Market Research)	Readex Research, Inc.	Jack Semler	Linda Taylor	Bruce Holdhusen	6/19/2009	10/31/2009

ABOUT THE MN/DOT RESEARCH SERVICES SECTION

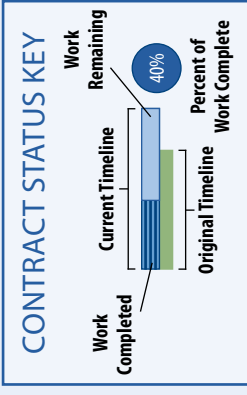
Mn/DOT's Research Services Section (RSS) manages the department's research program. RSS staff identify research needs and coordinate research projects for Mn/DOT and the Local Road Research Board, and coordinate Mn/DOT's involvement in state and national cooperative research programs such as the National 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.dot.state.mn.us/research to download research reports and products.



FUNDING SOURCE KEY

- LRRB Local Road Research Board
- SRP State Research Program
- SP&R State Planning and Research (FHWA)



RESEARCH SERVICES

Active Research Contracts in 2009

On-time delivery of results is a key performance measure for Mn/DOT's research program.

The Gantt chart below shows the original schedule (green bar) and the current schedule (blue bar), reflecting extensions because of scope changes and/or delays. The approximate percentage of the project completed as of November 2009 is shown by the numerical value in the right-most column. If the shaded portion of the blue bar stops earlier than November 2009, this may indicate that the project is behind schedule or was designed to have increased effort late in the project.

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2006	2007	2008	2009	2010	2011	2012	% of Work Complete
SP&R	\$4,635	\$0	2009-182	CTC & Associates LLC	Patrick Casey	Linda Taylor	Linda Taylor	MPR-9(008): Mn/DOT's 2009 Peer Exchange—Quantifying and Communicating the Value of Research								95%
LRRB	\$18,950	\$17,375	2007-092	MIS Sciences Corp.	Jeff Willis	Cory Johnson	Jake Akervik	Research Services and Local Road Research Board Web Site Hosting and Maintenance 2008-2009								90%
SP&R	\$97,500	\$67,500	2009-093 (92843)	Micky Ruiz	Micky Ruiz	Jake Akervik	Clark Moe	MPR-6(004): Implementation & Closeout Program Administration Support								90%
SRP/SP&R	\$99,203	\$78,040	2007-075 (94094)	CTC & Associates LLC	Patrick Casey	Cory Johnson	Jake Akervik	MPR-6(019): Technology Transfer Material Development—Phase III								90%
LRRB	\$45,400	\$43,130	2006-042 (89261 w023)	University of Minnesota	Craig Shankwitz	Glen Ellis	Shirlee Sherkow	INV 845-2: Analysis of Highway Design and Geometric Effects on Crashes								83%
SRP/SP&R	\$100,000	\$90,090	2009-059 (93423)	Dave Johnson	Dave Johnson	Linda Taylor	Cory Johnson	MPR-6(003): Innovation Program Development								83%
SRP/SP&R	\$109,890	\$95,605	2007-063	University of Minnesota	John Hourdos	Chris Roy/ Colleen Von-Wagner	Bruce Holdhusen	MPR-6(009): TH36 Full Closure Impacts—Highways for Life Corridor: To Close or Not to Close								81%
LRRB	\$52,980	\$50,331	2006-015	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								80%
LRRB	\$94,876	\$90,132	2007-002	University of Minnesota	Diwakar Gupta	Curt Turgeon, Tom Ravn	Alan Rindels	INV 871: Statistical Methods for Materials Testing								80%

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	Year				% of Work Complete
									2006	2007	2008	2009	
SRP/SP&R	\$310,000	\$246,843	2009-061 (89450 w07)	Project Information Services	Tim Malagon	Thomas Wiener	Clark Moe	MPR-6(033): TRACS Research and Implementation Project					
LRRB	\$30,000	\$21,500	2001-019	Mn/DOT Office of Materials	Timothy Clyne	Lou Tasa	Dan Warzala	INV 768: Geosynthetics in Roadway Design					
SRP	\$60,000	\$48,000	2008-004	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					
LRRB	\$55,000	\$50,050	2007-006	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					
SRP/SP&R	\$125,000	\$85,345	2007-095	The Kestrel Design Group, Inc.	L. Peter MacDonagh	Kenneth Graeve	Shirlee Sherkow	MPR-6(032): Designing Site-Specific Roadside Prairie or Grassland Seed Mixes					
LRRB/SRP/SP&R	\$63,500	\$50,800	2007-003	University of Minnesota	Randal Barnes	Thomas Burnham	Shirlee Sherkow	INV 872(TPF-5(148)): MnROAD Data Mining, Evaluation and Qualification, Phase 1					
SRP	\$109,562	\$71,215	2006-027	University of Minnesota - Duluth	Kurt Johnson	Sarma Straumantis	Debra Fick	Wetland Mitigation in Abandoned Gravel Pits					
LRRB	\$123,000	\$115,341	2007-005	University of Minnesota	Omid Mohseni	Mike Eastling	Shirlee Sherkow	INV 874: Assessment of the Underground Stormwater Management Devices Under High Flow Conditions					
LRRB	\$99,940	\$61,000	2007-008	University of Minnesota - Duluth	Taek Kwon	Brian Boder	Alan Rindels	INV 877: Advanced Dynamic LED Warning Signs for Rural Intersections Powered by Renewable Energy					
LRRB	\$45,000	\$30,000	2007-041	University of Minnesota	Divakar Gupta	Jim Faldesi	Alan Rindels	INV 880: Snow Plow Optimization					
SRP	\$95,197	\$61,380	2008-104	EVS	Paul Keranen	Farideh Amiri	Bruce Holdhusen	Snow Plow Training & Procedure Manual Project					
SRP	\$150,000	\$103,500	2006-041	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					
SRP	\$14,000	\$8,750	2008-014	University of Minnesota	Gina Baas	Cory Johnson	Linda Taylor	Access to Destinations Study, Administration 2008-2009					
SRP	\$150,000	\$105,000	2006-111	University of Minnesota	Gary Davis	Gene Hicks	Linda Taylor	Access to Destinations: Arterial Data Acquisition and Network-Wide Travel Time Estimation (Phase II)					
SRP	\$114,390	\$102,950	2006-030	University of Minnesota	Cathy French	Lowell Johnson	Shirlee Sherkow	Discrepancies in Shear Strength of Prestressed Beams with Different Specifications					
LRRB	\$90,000	\$14,825	2008-040	University of Minnesota	Jim Grothaus	Mark Maloney	Clark Moe	INV 998: FY2009 Operational Research Program for Local Transportation Groups OPERA					
SRP	\$99,500	\$83,580	2009-018	University of Minnesota	Kathleen Harder	Cassandra Isackson	Dan Warzala	Comparison of Dual-Phase and Static Signage					
SRP	\$76,000	\$68,000	2007-035	University of Minnesota	Nikos Papanikolopoulos	Lisa Austin	Alan Rindels	Analysis of Practical Methods for Counting Bicycling and Pedestrian Use of a Transportation Facility					
SRP	\$75,000	\$64,000	2009-062	HHH Institute of Public Affairs	Adeel Lari	Kenneth Burkey	Shirlee Sherkow	Study of Public Acceptance of Tolling Credits					

Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	Year				% of Work Complete
									2006	2007	2008	2009	
LRRB	\$126,042	\$74,995	2006-014	University of Minnesota	Lev Khazanovich	Jerry Geib	Clark Moe	INV 851: Allowable Axle Loads on Pavements					57%
LRRB	\$139,094	\$63,590	2006-007	Minnesota State University, Mankato	James Wilde	Tim Stahl	Dan Warzala	INV 844: Update of Vehicle Classification for County Road Pavement Design					56%
SRP	\$79,937	\$42,847	2006-032	Minnesota State University, Mankato	John Krenz	Jason Alcott	Dan Warzala	The Utility of Wildlife Crossings in Minnesota					56%
SRP/SP&R	\$19,000	\$10,000	2007-039 (94156)	Archwing Innovations, LLC	Ryan Anderson	Nelson Cruz	Cory Johnson	MPR-6(005): Next Generation of ARTS Tech Support and Maintenance Services					52%
LRRB	\$31,040	\$17,313	2006-006	Minnesota State University, Mankato	James Wilde	John Brunkhorst	Dan Warzala	INV 843-1: Predicting the Occurrence of Bumps in Overlays					50%
SRP	\$55,000	\$31,350	2008-008	University of Minnesota	Vladimir Cherkassky	Robert Edstrom	Dan Warzala	Statistical Analysis of the Soil Chemical Survey Data					50%
SRP	\$160,000	\$120,000	2007-028	University of Minnesota	Rajesh Rajamani	Gabe Guevara	Dan Warzala	Automated Vehicle Location, Data Recording and Applicator Control for Winter Road Maintenance					50%
SRP	\$186,000	\$139,500	2008-009	University of Minnesota	David Levinson	Brian Gage	Linda Taylor	Access to Destinations Phase 3: Measuring Accessibility by Automobile					50%
SRP	\$43,000	\$27,680	2007-082	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	\$17,763	\$17,763	2008-012 (89261 wo130)	University of Minnesota	Yngling Fan	Robert Vockrodt	Dan Warzala	Impact of Twin Cities Transitways on Regional Labor Market Accessibility: A Transportation Equity Perspective					50%
SRP	\$200,502	\$189,475	2008-021	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					50%
LRRB	\$92,624	\$43,800	2006-037	North Dakota State University	Magdy Abdelrahman	John Grindeland	Dan Warzala	INV 855: A Property-Based Specification for Coarse Aggregate in Pavement Applications					50%
SRP	\$160,000	\$86,000	2008-005	University of Minnesota	Omid Mohseni	Barbara Loida	Shirlee Sherkow	Assessment and Recommendation for Operation of Standard Sumps as Best Management Practices for Stormwater Treatment					50%
LRRB	\$25,992	\$12,996	2009-075 (2008-041, Task 2)	SRF Consulting Group, Inc.	Michael Marti	Mel Odens	Bruce Holdhusen	Sign Retro Reflectivity Standards Readiness: RIC 2009-2011 Task 2					50%
SP&R	\$39,600	\$18,535	2009-093 (92724)	Darlene Gorrill	Darlene Gorrill	Jake Akervik	Clark Moe	MPR-6(004): Implementation & Closeout Program Administration Support					47%
LRRB/SP&R	\$275,239	\$74,315	2009-095 (89261 wo79)	University of Minnesota	Lev Khazanovich	Shongtao Dai	Bruce Holdhusen	INV 854: TPF-5(148): Effects of Implements of Husbandry on Pavement Performance					44%
LRRB	\$33,500	\$11,203	2006-081	Mn/DOT Office of Materials	Eddie Johnson	N/A	Dan Warzala	INV 843-2: Predicting the Occurrence of Bumps in Overlays					43%
LRRB	\$40,000	\$16,000	2005-005	Mn/DOT Office of Materials	Matthew Lebens	Michael Sheehan	Alan Rindels	INV 825: Performance Monitoring of Olmsted CR 117/104 and Aggregate Base Material Update					43%
SRP/SP&R	\$230,798	\$86,136	2007-049	University of Minnesota	Jim Grothaus	Scott Bradley	Becky Lein	MPR 6(007): Hear Every Voice (HEV) Implementation & Training					40%

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Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Tech Liaison	Administrative Liaison	Project Title	Year					% of Work Complete			
									2006	2007	2008	2009	2010		2011	2012	
SRP	\$158,872	\$73,883	2007-034	University of Minnesota	John Nieber	Kenneth Graeve	Shirlee Sherkow	Wetlands: Role of Buffers in Upland Infiltration, Nutrient Absorption, and Wildlife Habitat								38%	
SRP	\$17,500	\$14,000	2008-091	Campbell Scientific	Jim Bliskie	John Siekmeier	Bruce Holdhusen	Implementation of Portable Field Moisture Technology, Phase II									33%
LRRB/SP&R	\$300,000	\$38,823	2006-088 (LRRBINV 868)	Mn/DOT Office of Materials	Timothy Clyne	Greg Johnson	Bruce Holdhusen	INV 868: MPR-6(029): HMA Surface Characteristics									33%
LRRB	\$40,863	\$12,259	2009-076 (2008-041 Task 3)	SRF Consulting Group, Inc.	Michael Marti	Rick West	Clark Moe	BMPs for Promoting Roadway Safety Maintenance: RIC 2009-2011 Task 3									30%
LRRB	\$56,200	\$13,600	2006-003	Mn/DOT Office of Materials	Shongtao Dai	Brian Noetzelman	Dan Warzala	INV 840-1: Performance of PG 52-34 Oil on Local Roads									29%
LRRB	\$50,000	\$15,000	2007-022 (LRRBINV 879)	Mn/DOT Office of Materials	Bernard Izevbekhai	Mark Maloney	Bruce Holdhusen	INV 879: Pervious Concrete Pavement in MnROAD Low Volume Road									29%
SRP	\$150,000	\$43,000	2008-007	University of Illinois	Erol Tutumluer	John Siekmeier	Nelson Cruz	Best Value Granular Material for Road Foundations									29%
LRRB	\$18,720	\$8,500	2009-001	Iowa State University	Omar Smadi	Thomas Behm	Alan Rindels	INV 888: Minnesota Local Agency Pavement Marking Practices, Phase 1									25%
LRRB/SP&R	\$49,597	\$12,399	2008-051 (89261 wo168)	University of Minnesota	Gina Baas	Linda Taylor	Sandy McCully	RSS Report Publication Services, 2010									25%
SRP/SP&R	\$800,000	\$200,000	2008-059	University of Minnesota	Max Donath	Linda Taylor	Linda Taylor	ITS Institute Mn/DOT Match—FY09/10									25%
SRP	\$79,441	\$31,776	2008-006	Iowa State University	Omar Smadi	Robert Gale	Shirlee Sherkow	Minnesota Truck Parking Study (Phase 2)									20%
SRP	\$179,752	\$41,343	2008-099	University of Minnesota	Diwakar Gupta	Robert Gale	Dan Warzala	Procedures for Highway Cost Allocation and Determination of Heavier Freight-Truck Permit Fees									20%
SRP/SP&R	\$113,952	\$42,720	2008-074	Minnesota State University, Mankato	James Wilde	Ryan Rohne	Sandy McCully	MPR-8(004): Development of a Concrete Maturity Test Protocol									20%
SP&R	\$500,000	\$65,284	2008-057	University of Minnesota	Max Donath	Susan Sheehan	Dan Warzala	MPR-8(002): Vehicle Telematics for Novice Teenage Driver Support System—Smartphone Based Novice Teenage Driver Support									13%
LRRB/SP&R	\$438,980	\$43,898	2006-087	University of Minnesota	Lev Khazanovich	Tim Clyne	Nelson Cruz	INV 867: TPF-5(149): Composite Pavements Design and Construction Guidelines for Thermally Insulated Concrete Pavements									11%
LRRB/SP&R	\$200,000	\$25,000	2006-099	Mn/DOT Office of Materials	Eddie Johnson	Roger Olson	Bruce Holdhusen	INV 864: MPR-6(022): Recycled Asphalt Pavements									11%
SRP/SP&R	\$99,981	\$3,891	2007-075 (95283)	CTC & Associates LLC	Patrick Casey	Cory Johnson	Jake Akevrik	MPR-6(019): Technology Transfer Material Development—Phase IV									10%
SRP	\$10,546	\$7,277	2009-140	University of Minnesota - Duluth	Todd Loushine	Todd Haglin	Bruce Holdhusen	Evaluation of Workforce Perceptions as a Means to Identify and Mitigate the Causes of Musculoskeletal Disorders									0%

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Funding Source	Total Cost	Amount Paid	Project #	Performing Organization	Investigator	Tech Liaison	Administrative Liaison	Project Title	Year				% of Work Complete	
									2006	2007	2008	2009		
SRP	\$34,997	\$0	2006-078	American Engineering Testing, Inc.	Dave Rettner	Bernard Izenbekhai	Bruce Holdhusen	IMP2006 #4: Implementation of the Hydraulic Fracture Test Specification for Coarse Aggregate						0%
LRRB	\$162,720	\$0	2005-085	Great Arc Technologies, Inc.	Michael Scanlon	Susan Miller	Clark Moe	INV 645: Crash Mapping and Analysis Tool (MnCMAT)						0%
SP&R	\$83,490	\$26,978	2009-093 (92329)	William Bunde	Bill Bunde	Cory Johnson	Clark Moe	MPR-6(004): Investigation & Evaluation of Closeout Memo Data for the Development of Additional Performance Measures						0%
SRP	\$32,000	\$0	2008-072	Mn/DOT Office of Materials	Matthew Lebens	N/A	Bruce Holdhusen	Incorporating GPS and Mapping Capability into Ground Penetrating Radar (GPR) Operations for Pavement Thickness Evaluation						0%
LRRB	\$25,000	\$0	2008-038 (89261 wo165)	University of Minnesota	Laurie McGinnis	Julie Skalliman, Mark Maloney	Linda Taylor	INV 869: TERRA Board Support—FY2010						0%
SRP/ SP&R	\$25,000	\$0	2009-117	American Engineering Testing, Inc.	Dave Rettner	John Hager, Steven Adamsky	Clark Moe	MPR-9(001): Stabilized Full Depth Reclamation (SFDR) Implementation						0%
SRP	\$165,000	\$0	2009-017	University of Minnesota	Cathy French	Keith Molnau	Dan Warzala	Full Depth Precast Concrete Bridge Deck Sys. Phase II (inverted tee)						0%
SRP	\$79,925	\$0	2009-022	University of Minnesota	Arturo Schultz	Todd Niemann	Nelson Cruz	Development of an Advanced Warning System for Structural Distress in Tied Arch Bridges						0%
SRP	\$99,000	\$0	2009-035	University of Minnesota	Gary Wyatt	Daniel Gullickson	Dan Warzala	Research and Assess the Farmer and Mn/DOT Economic and Environmental Costs and Benefits of Living Snow Fences Including Carbon Impacts						0%
SRP	\$74,929	\$0	2009-015	University of Minnesota	Zhirong Zhao	Kenneth Buckeye	Dan Warzala	Advancing the Public Interest in Public-Private Partnerships of State Highway Development						0%
LRRB	\$112,517	\$0	2009-012	University of Minnesota	Keith Knapp	Amy Marohn	Shirlee Sherkow	INV 890: Speed Impacts of Occasional Hazard Residential Street Warning Signs						0%
LRRB	\$30,000	\$0	2008-100	University of Minnesota	Diwakar Gupta	Richard Kjonas	Dan Warzala	INV 893: Optimal Contract Mechanism Design for Performance-Based Contracts						0%
LRRB	\$60,000	\$0	2008-090	Minnesota State University, Mankato	James Wilde	Rich Sanders	Clark Moe	Integrated Tools for Pavement Design and Management						0%
SRP/ SP&R	\$99,896	\$15,095	2008-070 (94458)	EVS	Paul Keranen	Linda Taylor	Bruce Holdhusen	MPR-8(006): Anti-icing Technology Implementation						0%
SRP	\$86,000	\$0	2009-098	University of Minnesota - Duluth	Eil Kwon	Brian Kary	Alan Rindels	Development of Freeway Management and Operational Strategies with IRIS-In-LOOP Simulation						0%
SRP	\$86,970	\$0	2009-021	Iowa State University	Omar Smadi	Mitchell Bartlett	Alan Rindels	Implementation, Training and Outreach for Mn/DOT Pavement Marking Tool—Phase II						0%
SRP	\$195,000	\$0	2009-023	University of Minnesota	Arturo Schultz	David Dahlberg	Nelson Cruz	Wakota Bridge Monitoring Program						0%
SRP	\$110,000	\$0	2009-014	University of Minnesota	Roberto Ballarini	Shongtao Dai	Dan Warzala	Mechanistic Modeling of Unbound Concrete Overlays						0%

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Active Multi-State Pooled Funds in 2009

Study Number	Title	Total Project Cost	Total MN Commitment	MN 2009 Commitment	Lead State or Agency	Mn/DOT Contact	Start Date	Projected End Date
SPR-2(207)	Transportation Management Center Pooled Fund Study	\$3,166,665	\$200,000	\$0	FHWA	Todd Kramasz	2000	Ongoing
SPR-3(017)/ TPF-5(193)	Midwest States Pooled Fund Crash Test Program	\$7,384,934	\$707,376	\$0	NE	Mike Elle	1991	Ongoing
SPR-3(020)	IVHS Study (ENTERPRISE)	\$1,170,000	\$120,000	\$30,000	IA	Ray Starr	1995	Ongoing
SPR-3(042)	Aurora Program	\$2,572,500	\$375,000	\$25,000	IA	Curt Pape	2003	Ongoing
SPR-3(049)	Urban Mobility Study	Over \$1,500,000	\$55,000	\$0	TX	Paul Czech	1997	Ongoing
TPF-5(004)	Long-Term Pavement Performance (LTPP) Specific Pavement Study (SPS) Traffic Data Collection	\$14,676,285	\$175,000	\$35,000	FHWA	George Ceyress	2003	2009
TPF-5(029)	High Occupancy Vehicle	\$1,540,000	\$150,000	\$150,000	FHWA	Janelle Anderson	2002	2010
TPF-5(035)	Pacific Northwest Snowfighters	\$290,000	\$30,000	\$10,000	WA	Gabe Guevara	2007	2010
TPF-5(039)	Falling Weight Deflectometer (FWD)	\$1,875,700	\$55,000	\$0	FHWA	David Bullock	2004	2009
TPF-5(046)	Transportation Curriculum Coordination Council Training Management and Development	\$950,000	\$75,000	\$0	FHWA	Catherine Betts	2002	2013
TPF-5(054)	Maintenance Decision Support System (MDSS)	N/A	\$200,000	\$50,000	SD	Curt Pape	Ongoing	Ongoing
TPF-5(069)	Core Program Services for a Highway Research, Development, and Technology Program	\$17,500,000	\$127,705	\$0	FHWA	Sue Lodahl	2004	Ongoing
TPF-5(092)	Clear Roads (Test & Evaluation of Materials, Equipment & Methods for Winter Maintenance)	\$905,000	\$150,000	\$25,000	WI	Linda Taylor	2004	Ongoing
TPF-5(099)	Evaluation of Low Cost Safety Improvements	\$2,850,000	\$195,000	\$0	FHWA	Dave Engstrom	2005	2011
TPF-5(105)	Transportation Library Connectivity Pooled Fund	\$20,000	\$100,000	\$20,000	WI	Sheila Hatchell	2005	2009
TPF-5(106)	Guidelines for Designing Bridge Piers and Abutments for Vehicle Collisions	\$430,000	\$0	\$0	TX	Dave Dahlberg	2007	2009
TPF-5(109)	TRB Core Program Services	\$17,500,000	\$255,410	\$127,705	FHWA	Sue Lodahl	2007	Ongoing
TPF-5(114)	Roadside Safety Research Program	\$550,000	\$250,000	\$50,000	WA	Michelle Elle, Nancy Yoo	2005	2009
TPF-5(116)	Investigation of the Fatigue Life of Steel Base Plate to Pole Connections for Traffic Structures	\$443,000	\$61,000	\$25,000	TX	Thomas Merritt	2005	2009
TPF-5(120)	Deer Vehicle Crash Information and Research (DVCIR) Center Pooled Fund	\$260,000	\$50,000	\$0	FHWA	Robert Weinholzer	2007	2009
TPF-5(127)	Consortium of Accelerated Pavement Testing (CAPT) and Technical Exchange Partnership	\$225,000	\$25,000	\$0	FHWA	Ben Worel	2007	2009
TPF-5(128)	Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base and Asphalt Pavement Material	\$725,000	\$75,000	\$0	FHWA	Tom Ravn	2007	2010
TPF-5(129)	Recycled Unbound Pavement Materials (MnROAD Study)	\$882,352	\$75,000	\$15,000	MN	Ben Worel	2007	2011
TPF-5(132)	Investigation of Low Temperature Cracking in Asphalt Pavements—Phase II	\$420,000	\$100,000	\$20,000	MN	Ben Worel	2007	2011
TPF-5(134)	PCC Surface Characteristics— Rehabilitation (MnROAD Study)	\$275,000	\$75,000	\$15,000	MN	Bernard Izevbekhai	2007	2010
TPF-5(135)	Tire Pavement Noise Research Consortium	\$163,000	\$25,000	\$15,000	WA	Bernard Izevbekhai	2006	2011
TPF-5(139)	PCC Surface Characteristics: Tire-Pavement Noise Program Part III	\$690,000	\$55,000	\$0	IA	Bernard Izevbekhai	2005	2010
TPF-5(148)	Effects of Implements of Husbandry “Farm Equipment”	\$433,000	\$105,000	\$0	MN	Shongtao Dai	2007	2010
TPF-5(149)	Design and Construction Guidelines for Thermally Insulated Concrete Pavements (MnROAD Study)	\$455,000	\$296,800	\$20,000	MN	Tim Clyne	2007	2011
TPF-5(153)	Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements (MnROAD Study)	\$335,000	\$75,000	\$15,000	MN	Ben Worel	2007	2012
TPF-5(154)	Census Transportation Planning Products (CTPP) from the American Community Survey	\$1,428,704	\$102,546	\$0	FHWA	Jonette Kreideweis	2007	2012
TPF-5(156)	Mississippi Valley Freight Coalition Pooled Fund Study	\$425,000	\$100,000	\$25,000	WI	Dave Christianson	2007	2009
TPF-5(159)	Technology Transfer Concrete Consortium	\$299,000	\$25,000	\$5,000	IA	Maria Masten	2007	2012

cont. ➔

Active Multi-State Pooled Funds in 2009, cont.

Study Number	Title	Total Project Cost	Total MN Commitment	MN 2009 Commitment	Lead State or Agency	Mn/DOT Contact	Start Date	Projected End Date
TPF-5(165)	Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements	\$360,000	\$60,000	\$0	MN	Tom Burnham	2007	2011
TPF-5(171)	Non-Intrusive Traffic Detection Systems III	\$225,000	\$15,000	\$0	MN	Jerry Kotzenmacher	2007	2009
TPF-5(174)	Construction of Crack-Free Bridges—Phase II	\$639,000	\$75,000	\$15,000	KS	Paul Kivisto	2007	2011
TPF-5(177)	Improving Resilient Modulus (MR) Test Procedures for Unbound Materials	\$340,000	\$40,000	\$20,000	FHWA	Maureen Jensen	2009	2010
TPF-5(179)	Evaluation of Test Methods for Permeability (Transport) and Development of Performance Guidelines for Durability	\$883,000	\$87,000	\$25,000	IN	Maria Masten	2008	2011
TPF-5(187)	Updating U.S. Precipitation Frequency Estimates for the Midwestern Region	\$1,191,580	\$200,001	\$33,333	FHWA	Andrea Hendrickson	2008	TBD
TPF-5(190)	Northwest Passage, Phase III	\$200,000	\$25,000	\$25,000	MN	Todd Kramasz	2008	2009
TPF-5(192)	Loop and Length Based Classification Pooled Fund	\$450,000	\$30,000	\$15,000	FHWA	Gene Hicks	2008	2009
TPF-5(196)	2009 National Asset Management Conference	\$70,000	\$10,000	\$10,000	FHWA	Matt Koukol	2009	2009
TPF-5(197)	The Impact of Wide-Base Tires on Pavement Damage: A National Study	\$750,000	\$100,000	\$25,000	FHWA	Shongtao Dai	2009	2012
TPF-5(198)	Urban Mobility Study—2009 Continuation—was SPR-3(049)	\$1,375,000	\$165,000	\$165,000	TX	Paul Czech	2009	2010
TPF-5(202)	HY-8 Culvert Analysis Program—Phase III of the Development Efforts	\$110,000	\$30,000	\$10,000	FHWA	Petra DeWall	2009	2011
TPF-5(209)	Transportation Curriculum Coordination Council (TCCC)	Over \$5,000,000	\$75,000	\$15,000	FHWA	Catherine Betts	2009	2012
TPF-5(213)	Performance of Recycled Asphalt Shingles in Hot Mix Asphalt	\$680,000	\$85,000	\$42,500	MO	Roger Olson	2009	2010
TPF-5(215)	Transportation Engineering and Road Research Alliance (TERRA)	\$120,000	\$25,000	\$5,000	MN	Maureen Jensen	2009	2014
TPF-5(218)	Clear Roads Test & Evaluation of Materials, Equipment and Methods for Winter Maintenance	Unknown	\$275,000	\$275,000	MN	Tom Peters	2009	2011
TPF-5(409)/ TPF-5(092)	National Cooperative Highway Research Program (NCHRP)	N/A	Ongoing	\$603,287	FHWA	Linda Taylor	N/A	Ongoing

RESEARCH SERVICES STATISTICS

(Calendar Year 2009)

Total active contracts for research and implementation	217
New contracts initiated	59
Contracts closed out	74
Reports and implementation products	44

Library Statistics

(Estimated for Calendar Year 2009)

Library materials circulated	16,897
New materials acquired	802
Questions answered	1,220
Literature searches	389
Interlibrary loans	876



Produced by CTC & Associates for:

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RESEARCH

2009 Local Road Research Board At-A-Glance

This publication provides a guide to the Local Road Research Board's 2009 research activities. It includes a graphical account of progress on all 2009 active research projects; a list of reports and research implementation products completed in 2009; 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

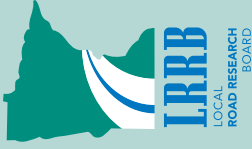
About LRRB

For more than 45 years, the LRRB has brought the latest developments in transportation research to the state's city and county engineers. Research applications range from cold-in-place recycling with foamed asphalt to the use of pervious concrete for stormwater management.

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

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

For more information about the projects listed in this publication, go to www.lrrb.org and search for reports and Technical Summaries or initiate queries. 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 a guide to pavement management systems, a training module on selecting pavement rehabilitation techniques, the Project Memo Writer, the Geosynthetic Design Guide, the Minnesota Research Test Section Tracking database and the Mix Asphalt Design Tool.



LRRB RESEARCH

Active Research Projects in 2009

On-time delivery of results is a key performance measure for Mn/DOT's research program.

The Gantt chart below shows the original schedule (green bar) and the current schedule (blue bar), reflecting extensions because of scope changes and/or delays. The approximate percentage of the project completed as of November 2009 is shown by the numerical value in the right-most column. If the shaded portion of the blue bar stops earlier than November 2009, this may indicate that the project is behind schedule or was designed to have increased effort late in the project.

An alternate sorting of these projects according to their end date can be found in the *Research Services 2009 At-A-Glance*.

FUNDING SOURCE KEY

- LRRB Local Road Research Board
- SP&R State Planning & Research (FHWA)
- SRP State Research Program

PROJECT STATUS KEY

Total Cost	Amount Paid	Funding Source	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	2006	2007	2008	2009	2010	2011	2012	% of Work Complete
\$490,845	\$490,845	LRRB	2008-015	University of Minnesota	Jim Grothaus	Julie Skallman	Cory Johnson	INV 668: Local Technical Assistance Program (LTAP)								100%
\$475,000	\$0	LRRB/SP&R	2007-093	University of Minnesota	Mihai Marasteanu	Benjamin Worel	Bruce Holdhusen	INV 865, TPF-5(132): Low Temperature Cracking in Asphalt, Phase II								0%
\$438,980	\$43,898	LRRB/SP&R	2006-087	University of Minnesota	Lev Khazanovich	Tim Clyne	Nelson Cruz	INV 867, TPF-5(149): Composite Pavements Design and Construction Guidelines for Thermally Insulated Concrete Pavements								11%
\$300,000	\$38,823	LRRB/SP&R	2006-088	Mn/DOT Office of Materials	Timothy Clyne	Greg Johnson	Bruce Holdhusen	INV 868: MPR-6(029): HMA Surface Characteristics								33%
\$275,239	\$74,315	LRRB/SP&R	2009-095	University of Minnesota	Lev Khazanovich	Shongtao Dai	Bruce Holdhusen	INV 854, TPF-5(148): Effects of Implements of Husbandry on Pavement Performance								44%
\$200,474	\$200,472	LRRB	2006-080	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								100%
\$200,000	\$25,000	LRRB/SP&R	2006-099	Mn/DOT Office of Materials	Eddie Johnson	Roger Olson	Bruce Holdhusen	INV 864: MPR-6(022): Recycled Asphalt Pavements								11%
\$162,720	\$0	LRRB	2005-085	Great Arc Technologies, Inc.	Michael Scanlon	Susan Miller	Clark Moe	INV 645: Crash Mapping and Analysis Tool (MnCMAT)								0%
\$139,094	\$63,590	LRRB	2006-007	Minnesota State University Mankato	James Wilde	Tim Stahl	Dan Warzala	INV 844: Update of Vehicle Classification for County Road Pavement Design								56%
\$126,042	\$74,995	LRRB	2006-014	University of Minnesota	Lev Khazanovich	Jerry Geib	Clark Moe	INV 851: Allowable Axle Loads on Pavements								57%

Total Cost	Amount Paid	Funding Source	Project #	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	Project Title	Year				% of Work Complete	
									2006	2007	2008	2009		2010
\$123,000	\$115,341	LRRB	2007-005	University of Minnesota	Omid Mohseni	Mike Eastling	Shirlee Sherkow	INV 874: Assessment of the Underground Stormwater Management Devices Under High Flow Conditions						
\$112,517	\$0	LRRB	2009-012	University of Minnesota	Keith Knapp	Amy Marohn	Shirlee Sherkow	INV 890: Speed Impacts of Occasional Hazard Residential Street Warning Signs						
\$112,500	\$112,500	LRRB	2008-038 (89261 w0107)	University of Minnesota	Laurie McGinnis	Julie Skallman, Mark Maloney	Cory Johnson	INV 869: TERRA Board Support—FY2009						
\$25,000	\$0	LRRB	2008-038 (89261 w0165)	University of Minnesota	Laurie McGinnis	Julie Skallman, Mark Maloney	Linda Taylor	INV 869: TERRA Board Support—FY2010						
\$109,984	\$0	LRRB/SRP	2009-008 (94079)	Minnesota State University, Mankato	James Wilde	Gregory Coughlin	Nelson Cruz	INV 886: Cost-Effective Pavement Preservation Solutions for the Real World						
\$15,000	\$0	LRRB/SRP	2009-008 (LAB886)	Mn/DOT Office of Materials	Tom Wood	Gregory Coughlin	Nelson Cruz	INV 886: Cost-Effective Pavement Preservation Solutions for the Real World						
\$99,940	\$61,000	LRRB	2007-008	University of Minnesota - Duluth	Taek Kwon	Brian Boder	Alan Rindels	INV 877: Advanced Dynamic LED Warning Signs for Rural Intersections Powered by Renewable Energy						
\$98,715	\$97,486	LRRB	2006-042 (91415)	CH2M HILL	Howard Preston	Glen Ellis	Shirlee Sherkow	INV 845-1: Analysis of Highway Design and Geometric Effects on Crashes						
\$45,400	\$43,130	LRRB	2006-042 (89261 w023)	University of Minnesota	Craig Shankwitz	Glen Ellis	Shirlee Sherkow	INV 845-2: Analysis of Highway Design and Geometric Effects on Crashes						
\$94,876	\$90,132	LRRB	2007-002	University of Minnesota	Diwaker Gupta	Curt Turgeon, Tom Ravn	Alan Rindels	INV 871: Statistical Methods for Materials Testing						
\$92,624	\$43,800	LRRB	2006-037	North Dakota State University	Magdy Abdelrahman	John Grindeland	Dan Warzala	INV 855: A Property-Based Specification for Coarse Aggregate in Pavement Applications						
\$90,000	\$14,825	LRRB	2008-040	University of Minnesota	Jim Grothaus	Mark Maloney	Clark Moe	INV 998: FY2009 Operational Research Program for Local Transportation Groups OPERA						
\$85,000	\$0	LRRB	2009-175	SRF Consulting Group, Inc./ Minnesota State University, Mankato	James Wilde, Michael Marti	Michael Sheehan	Clark Moe	Traffic Generator						
\$83,428	\$0	LRRB/SRP	2009-036	University of Minnesota	John Nieber	Petronella DeWall	Nelson Cruz	INV 891: Performance Assessment of Oversized Culverts to Accommodate Fish Passage						
\$82,400	\$22,400	LRRB	2007-009 (LAB878)	The Kestrel Design Group, Inc.	Matthew Lebens	Larry Matsumoto	Bruce Holdhusen	INV 878: Porous Asphalt Pavement Performance in Cold Regions						
\$1,729	\$1,729	LRRB	2007-009 (93093)	Department of Health	N/A	Larry Matsumoto	Bruce Holdhusen	Porous Asphalt Pavement Performance in Cold Weather Water Samples						
\$80,752	\$0	LRRB	2009-077	SRF Consulting Group, Inc./ Greer & Associates/Minnesota State University, Mankato	Michael Marti, James Wilde, Richard Kronick	Gary Danielson	Clark Moe	Pavement DVD—Do the Right Thing at the Right Time at the Right Place: RIC 2009-2011 Task 4						
\$77,905	\$77,905	LRRB	2006-039	University of Minnesota	Mihal Marasteanu	John Garrity	Dan Warzala	INV 856: Investigation of In-Place Asphalt Film Thickness and Performance of Minnesota Hot Mix Asphalt Mixtures						
\$63,500	\$50,800	LRRB/SRP/SP&R	2007-003	University of Minnesota	Randal Barnes	Thomas Burnham	Shirlee Sherkow	INV 872/TP-5(148): MnROAD Data Mining, Evaluation and Qualification, Phase 1						
\$60,000	\$0	LRRB	2008-090	Minnesota State University, Mankato	James Wilde	Rich Sanders	Clark Moe	Integrated Tools for Pavement Design and Management						

Completed LRRB Research Reports and Implementation Products in 2009

Report Number	Project Title	Cost	Funding Source	Performing Organization	Investigator	Technical Liaison	Administrative Liaison
2009-06	INV 815: Implementation of the MEPDG for New and Rehabilitated Pavement Structures for Design of Concrete and Asphalt Pavements in Minnesota	\$292,385	LRRB/SRP	University of Minnesota	Lev Khazanovich, Mihai Marasteanu	Gerard Geib	Dan Warzala
2009-08	INV 830: Evaluating Roadway Subsurface Drainage Practices	\$186,735	LRRB	University of Minnesota	John Nieber, Gary Sands	Stephen Schneider, Andrew Eller	Nelson Cruz
2009-27	INV 847: Use of Fly Ash for Reconstruction of Bituminous Roads	\$161,553	LRRB	University of Minnesota	Paul Bloom, Tuncer Edil	John Siekmeier	Nelson Cruz
2009-32	INV846: Hydraulic, Mechanical and Leaching Characteristics of Recycled Materials	\$153,875	LRRB	University of Minnesota	Satish Gupta	John Siekmeier	Nelson Cruz
2009-03	INV 848: Warning Efficacy of Active Versus Passive Warnings for Unsignalized Intersection and Mid-Block Pedestrian Crosswalks	\$118,908	LRRB	University of Minnesota	Thomas Smith, Nikos Papanikolopoulos	Deb Bloom	Dan Warzala
2009-21	INV 850: Mechanistic Modeling of Unbound Granular Materials	\$105,000	LRRB	University of Minnesota	Kimberly Hill, Lev Khazanovich	Lee Amundson	Nelson Cruz
2009-05	INV 831: Investigation of Stripping in Minnesota Class 7 (RAP) and Full-Depth Reclamation Base Materials	\$92,397	LRRB/SRP	North Dakota State University	Magdy Abdelrahman	Tim Andersen	Nelson Cruz
2009-04	INV 842: Best Practices for Dust Control on Aggregate Roads	\$75,000	LRRB	Mn/DOT Office of Materials	Eddie Johnson	John McDonald	Shirlee Sherkow
2009-13	INV 858: Crack and Concrete Deck Sealant Performance	\$75,000	LRRB/SRP	University of Minnesota	Arturo Schultz, Cathy French	Jim Lilly	Nelson Cruz
2009-17	INV 852: Subsurface Drainage Manual for Pavements in Minnesota	\$71,638	LRRB	University of Minnesota	John Nieber	Dan Sauve	Alan Rindels
2009-18	INV 861: Preventive Maintenance Best Management Practices of Hot Mix Asphalt Pavements	\$71,050	LRRB	Mn/DOT Office of Materials	Thomas Wood, Erland Lukanen	Tim Stahl	Shirlee Sherkow
2009RIC11	INV 645: Implementation of Pavement Management in Minnesota	\$70,007	LRRB	SRF Consulting Group, Inc.	Michael Marti	Glenn Engstrom	Clark Moe
2009-01	INV 862: Development of a Real-Time Arterial Performance Monitoring System Using Traffic Data Available from Existing Signal Systems	\$70,000	LRRB	University of Minnesota	Henry Liu, Wenteng Ma Xinkai Wu, Heng Hu	Eric Drager	Shirlee Sherkow
2009-12	INV 860: Using the Dynamic Cone Penetrometer and Light Weight Deflectometer for Construction Quality Assurance	\$60,561	LRRB	Mn/DOT Office of Materials	John Siekmeier	Merle Earley	Shirlee Sherkow
2009-02	INV 773-3: Oak Grove Tire Shreds Project: Tire Shreds Below the Seasonal Groundwater Table, Years 2006-2008	\$57,872	LRRB	Mn/DOT Office of Materials	Robert Edstrom	Ronald Mortensen	Dan Warzala
2009-25	INV 876: Preventive Maintenance for Recreational Trails	\$53,569	LRRB	Mn/DOT Office of Materials	Roger Olson, Erland Lukanen	Doug Schwartz	Shirlee Sherkow
2009RIC12	INV 645: Stormwater Maintenance BMP Resource Guide	\$51,747	LRRB	SRF Consulting Group, Inc.	Michael Marti	Mike Sheehan	Clark Moe
2009-20	INV 870: Cost Analysis of Alternative Culvert Installation Practices in Minnesota	\$50,663	LRRB	University of Minnesota	John Nieber, Bruce Wilson	Alan Forsberg, Susan Miller	Alan Rindels
2009-15	INV 826: Best Practices for RAP Use Based on Field Performance	\$30,789	LRRB	Mn/DOT Office of Materials	Eddie Johnson, Jim McGraw	John Brunkhorst, David Linell	Dan Warzala
2009RIC02	INV 645: Innovative Contracting Methods	\$25,565	LRRB	SRF Consulting Group, Inc.	Michael Marti	Tom Behm	Clark Moe
2009-09	INV 873: Recycled Pavements Using Foamed Asphalt in Minnesota	\$11,000	LRRB	Mn/DOT Office of Materials	Roger Olson, Andrew Eller	Mark Maloney	Sandy McCully
2009-19	INV 879: MnROAD Cell 64 Pervious Concrete: Third Year Performance Report	N/A	LRRB	Mn/DOT Office of Materials	Ryan Rohne, Bernard Izevbekhai	N/A	N/A
TRS0901	INV 881: Methods and Practices for Control of Canada Thistle	N/A	LRRB/SRP	Darlene Gorrill	Darlene Gorrill	Linda Taylor	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.

IMPLEMENTATION AND EDUCATION

Over the last 15 years, the LRRB has sponsored more than 200 individual research projects on a variety of topics. We have also helped local communities offer pavement management, rural safety and snowplow sander calibration workshops; update their crash analysis software; explore the environmental benefits of porous pavements; and evaluate the performance of stormwater treatment technology.

KNOWLEDGE BUILDING PRIORITIES

In 2009 LRRB updated its Knowledge Building Priorities, which define long-term, complex transportation issues affecting local government agencies that could be addressed with research. Priorities include roadway safety, use of recycled and alternative pavement materials, innovative contracting methods and the reduction of environmental impacts.



Produced by CTC & Associates for:

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www.dot.state.mn.us/research

Research Highlights

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

The SMART-SIGNAL system (presented in Report 2009-01) was developed to collect and archive high-resolution traffic signal data and automatically generate real-time performance measures such as travel time, queue length and intersection delay. Engineers can use this data to optimize timing schedules on each traffic signal to reduce congestion without additional road construction. The LRRB also sponsored efforts to evaluate the effectiveness of pavement preventive maintenance techniques on recreational trails (2009-25) and roadway subsurface drainage practices (2009-08).

The RIC produced a number of very useful guides for local agencies including Stormwater Maintenance Best Management Practices Resource Guide (2009RIC12), Innovative Contracting Methods (2009RIC02) and the educational toolbox Implementation of Pavement Management in Minnesota (2009RIC11).

For more LRRB research highlights and links to Technical Summaries, go to www.dot.state.mn.us/research.



The LRRB-sponsored report 2009-25, Preventive Maintenance for Recreational Trails, describes how techniques designed for roadways such as chip sealing (pictured here) need to be modified for use on trails.



Minnesota Department of Transportation

FHWA State Planning and Research Program

2009 At-A-Glance

This publication provides a guide to Mn/DOT Research Services' use of 2009 State Planning & Research Part II funding. It includes a list of completed SP&R-sponsored projects, active single-state SP&R research contracts and active multi-state pooled fund studies that Mn/DOT leads or in which it participates.

SP&R funds are received from the Federal Highway Administration for Mn/DOT planning and research activities. The most recent transportation authorization act—the Safe, Accountable, Flexible, Efficient Transportation Equity Act—requires that a minimum of 25 percent of these funds are to be used specifically for research (designated “SP&R Part II”) to address state-specific research needs, with the remaining portion going to planning, administration and other needs (“SP&R Part I”).

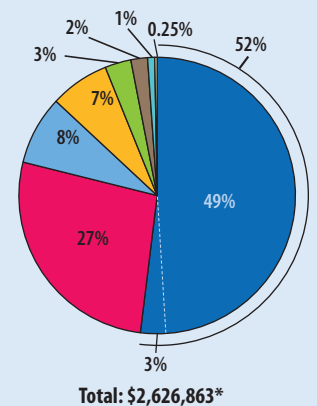
SP&R Part II funds can be used for participation in multi-state pooled fund efforts or in single-state efforts. Multi-state pooled funds allow Mn/DOT to multiply its research dollars, saving taxpayer money. Mn/DOT has been a leader in this area. SP&R funds enable Mn/DOT to invest in long-range strategies and research into innovative new technologies. Some highlights of these efforts involve new pavement design testing at the MnROAD facility, intelligent compaction of soils, optimization of maintenance and construction techniques, and projects geared toward meeting regional and local needs. SP&R funds are often used to fund implementation and technology transfer efforts to ensure that developed innovations are understood and used by Mn/DOT districts and local governments.



U.S. Department of Transportation
Federal Highway Administration

2009 SP&R Part II Funding by Mn/DOT Strategic Research Area

	Infrastructure Preservation	52%	\$1,357,851
	Roads: 49%		\$1,287,839
	Bridges: 3%		\$70,012
	Congestion Management	27%	\$710,000
	Traffic Safety	8%	\$202,845
	Innovative Project Delivery	7%	\$190,514
	Green Roads	3%	\$89,463
	Organization Transformation	2%	\$45,000
	Multimodal Infrastructure	1%	\$25,000
	Build Trust from Public and Legislature	0.25%	\$6,190



*Excludes administrative projects, but includes some projects without an assigned end-user product for which an associated research area could be determined.

2009 SP&R Part II Funding Distribution

	Mn/DOT-led Multi-state Pooled Funds	13%	\$390,000
	Participation in Other Multi-state Pooled Funds	52%	\$1,571,825
	Single-state SP&R Projects	35%	\$1,040,864
	Program and Administrative Support:	9%	\$277,914
	Implementation:	23%	\$694,661
	MnROAD:	2%	\$68,289
	Total:		\$3,002,689*

*Figures are rounded to the nearest dollar and percent.

2009 Completed SP&R Reports

"N/A" in the cost column indicates that this report was funded by administrative sources or as part of a project already listed on the 2009 Active Contracts list.

A mark in the "TS?" column indicates that a Technical Summary is or will be available for this project in the 2009 Annual Report or at www.dot.state.mn.us/research.

FUNDING SOURCE KEY

SP&R	State Planning & Research (FHWA)
SP&R /SRP	Co-funded by SP&R and the State Research Program
SP&R/MAT	Co-funded by SP&R and the Mn/DOT Office of Materials

Report Number	Cost	Funding Source	Project Title	Performing Organization	Investigator	Technical Liaison	Administrative Liaison	TS?
2009-14	\$425,000	SP&R/MAT	Implementation of Intelligent Compaction Performance Based Specifications in Minnesota	Iowa State University	David White	John Siekmeier	Clark Moe	X
2009-22	N/A	SP&R	2008 MnROAD Phase II Construction Report	Mn/DOT Office of Materials	Ann Johnson, Tim Clyne, Ben Worel	N/A	N/A	
2009-26	N/A	SP&R	Demonstration of Concrete Maturity Test Process on the TH-694/TH-35E Interchange—Unweave the Weave	Mn/DOT Office of Materials	Bernard Izevbekhai	N/A	N/A	
2009-30	N/A	SP&R	Ultrathin Bonded Wearing Course Performance Update, Minnesota	Mn/DOT Office of Materials	Ahmed Ali Ahmed	N/A	N/A	
2009-35	\$84,457	SP&R	Procedures to Use and Manage IC Data in Real Time	CNA Consulting Engineers, Inc.	Lee D. Petersen	Rebecca Embacher, Tim Andersen	Clark Moe	X
2009-42	N/A	SP&R	Asphalt Mixture and Binder Fracture Testing for 2008 MnROAD Construction	Mn/DOT Office of Materials	Mihai Marasteanu	N/A	N/A	
N/A (Project 2007-084)	\$35,630	SP&R/SRP	Implementation of Steel Bridge Maintenance Planning	University of Minnesota	Arturo Schulz	Jim Pierce	Bruce Holdhusen	X
TRS0902	N/A	SRP/SP&R	Anti-icing in Winter Maintenance Operations: Examination of Research and Survey of State Practice	CTC & Associates LLC	Pat Casey, Chris Kline	Linda Taylor	Jake Akervik	

Pooled Fund Highlights

For more details and additional highlights, please see the *Research Services 2009 Annual Report*.

Clear Roads Test and Evaluation of Materials, Equipment and Methods for Winter Maintenance, TPF-5(218) *continued from* TPF-5(092)

Clear Roads funds and oversees field testing of winter maintenance materials, methods and equipment, funding two to three research projects annually focused on identifying innovative solutions, evaluating their effectiveness for managing a range of winter conditions, and assessing their practicality and ease of use within varied highway maintenance organizational structures. Clear Roads has grown to 18 member states and is currently expanding its scope to focus on state agency needs, technology transfer and implementation, including support for staff in the field. This pooled fund project supports state DOTs' efforts to develop industry standards, performance measures and cost-benefit analyses, and practical field guides and training curricula. It also supports peer exchanges and collaborative efforts between winter maintenance specialists and promotes public education related to winter maintenance and winter driving safety. www.clearroads.org

LEADING MULTI-STATE COLLABORATIONS

Mn/DOT has been a leader in multi-state pooled fund efforts, spearheading 12 pooled funds including investigations of Non-Intrusive Traffic Detection Technologies (TPF-5(171)), Intelligent Transportation Systems Across the Northwest Passage (TPF-5(190)) and, with the onset of 2010, the Clear Roads Winter Highway Operations Pooled Fund (TPF-5(218)).

Midwest States Pooled Fund Crash Test Program, SPR-3(017)/TPF-5(193)

This 13-member pooled fund program is dedicated to making the roadside less hazardous to motorists by evaluating the performance and safety of standard roadside hardware designs used by various state highway agencies. The program is recognized as a global leader in the research, development and computer modeling of new roadside safety hardware and has developed numerous guardrail technologies, bridge railings, work-zone devices and other technologies that have been adopted nationwide. The program is currently developing guidelines for the use of roadside safety structures and performing a long-term accident investigation study. engineering.unl.edu/specialty-units/mwrsf

Transportation Management Center Pooled Fund Study, SPR-2(207)

This pooled fund study funds, oversees and disseminates the results of projects related to transportation management centers used by public agencies to monitor and report on roadway and travel conditions; communicate with local interests, emergency services and the traveling public; and proactively manage and control traffic to mitigate congestion and improve the reliability of travel. Twenty-seven projects have been completed, initiated or approved since the program's inception, including best practices for Changeable Message Signs and manuals on TMC operations, staffing, business planning and performance monitoring. Ongoing projects cover topics such as driver use of real-time travel time information, human factors design guidelines and management of contractor services. tmcops.fhwa.dot.gov/overview.cfm

Other Active Multi-State Pooled Funds in 2009

Number of Participating States excludes FHWA but in some cases includes Canadian provinces.

Study Number	Title	Total Project Cost	Total MN Commitment	Mn 2009 Commitment	Number of Participating States	Lead State or Agency	Mn/DOT Contact	Start Date	End Date
SPR-2(207)	Transportation Management Center Pooled Fund Study	\$3,166,665	\$200,000	\$0	28	FHWA	Todd Kramasz	2000	Ongoing
SPR-3(017)/ TPF-5(193)	Midwest States Pooled Fund Crash Test Program	\$7,384,934	\$707,376	\$0	16	NE	Mike Elle	1991	Ongoing
SPR-3(020)	IVHS Study (ENTERPRISE)	\$1,170,000	\$120,000	\$30,000	9	IA	Ray Starr	1995	Ongoing
SPR-3(042)	Aurora Program	\$2,572,500	\$375,000	\$25,000	17	IA	Curt Pape	2003	Ongoing
SPR-3(049)	Urban Mobility Study	Over \$1,500,000	\$55,000	\$0	13	TX	Paul Czech	1997	Ongoing
TPF-5(004)	Long-Term Pavement Performance (LTPP) Specific Pavement Study (SPS) Traffic Data Collection	\$14,676,285	\$175,000	\$35,000	24	FHWA	George Cepress	2003	2009
TPF-5(029)	High Occupancy Vehicle	\$1,540,000	\$150,000	\$150,000	10	FHWA	Janelle Anderson	2002	2010
TPF-5(035)	Pacific Northwest Snowfighters	\$290,000	\$30,000	\$10,000	9	WA	Gabe Guevara	2007	2010
TPF-5(039)	Falling Weight Deflectometer (FWD)	\$1,875,700	\$55,000	\$0	12	FHWA	David Bullock	2004	2009
TPF-5(046)	Transportation Curriculum Coordination Council Training Management and Development	\$950,000	\$75,000	\$0	15	FHWA	Catherine Betts	2002	2013
TPF-5(054)	Maintenance Decision Support System (MDSS)	N/A	\$200,000	\$50,000	17	SD	Curt Pape	Ongoing	Ongoing
TPF-5(069)	Core Program Services for a Highway Research, Development, and Technology Program	\$17,500,000	\$127,705	\$0	20	FHWA	Sue Lodahl	2004	Ongoing
TPF-5(092)	Clear Roads (Test & Evaluation of Materials, Equipment & Methods for Winter Maintenance)	\$905,000	\$150,000	\$25,000	15	WI	Linda Taylor	2004	Ongoing
TPF-5(099)	Evaluation of Low Cost Safety Improvements	\$2,850,000	\$195,000	\$0	28	FHWA	Dave Engstrom	2005	2011
TPF-5(105)	Transportation Library Connectivity Pooled Fund	\$20,000	\$100,000	\$20,000	23	WI	Sheila Hatchell	2005	2009
TPF-5(109)	TRB Core Program Services	\$17,500,000	\$255,410	\$127,705	22	FHWA	Sue Lodahl	2007	Ongoing
TPF-5(114)	Roadside Safety Research Program	\$550,000	\$250,000	\$50,000	8	WA	Michelle Elle, Nancy Yoo	2005	2009



SP&R funding provides increased opportunities to use the MnROAD cold-region testing laboratory, a unique platform for testing road-building materials and designs. MnROAD features two road segments—3.5 miles of mainline highway and 2.5 miles of low-volume roadway—divided into 52 test cells.

THE NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

The National Cooperative Highway Research Program receives 5.5 percent of all states' SP&R Part II funding to feed the national need for research into highway planning, design, construction, operations and maintenance. This research includes the evaluation of fundamental new technologies and techniques, such as the move to Mechanistic-Empirical Pavement Design, and sharing best practices between states, as with [NCHRP 08-62, "Transportation Performance Management Programs—Insight from Practitioners,"](#) the panel chaired by Mark Larsen of Mn/DOT's Office of Investment Management. Mn/DOT is well-represented on panels for NCHRP projects as well as for other cooperative programs such as the Transit Cooperative Research Program and the Strategic Highway Research Program 2.

Active Single-State SP&R Contracts in 2009

FUNDING SOURCE KEY

SP&R State Planning & Research (FHWA)
 SP&R/LRRB Co-funded by SP&R and the Local Road Research Board
 SP&R/SRP Co-funded by SP&R and the State Research Program

Study Number	Mn/DOT Tracking Number	Title	Funding Source	Total Project Cost	Total Amount Paid	2009 SP&R Funds Committed	Performing Organization	Primary Investigator	Technical Liaison	Administrative Liaison	Start Date	Projected End Date
MPR-6(003)	2009-059 (90901)	Strategic Program Development	SP&R/SRP	\$140,690	\$139,283	\$49,080	Trisessential	Steve Beise	Linda Taylor	Cory Johnson	8/6/2007	4/30/2009
MPR-6(003)	2009-059 (93423)	Innovation Program Development	SP&R/SRP	\$100,000	\$90,090	\$48,913	Dave Johnson	Dave Johnson	Linda Taylor	Cory Johnson	10/1/2008	11/30/2010
MPR-6(003)	2009-059 (93998)	Library Information Resources Update	SP&R/SRP	\$23,130	\$23,130	\$18,504	Lowell Benson	Lowell Benson	James Byerly	Sheila Hatchell	3/30/2009	7/31/2009
MPR-6(004)	2009-093 (92843)	Implementation & Closeout Program Administration Support	SP&R	\$97,500	\$67,500	\$46,248	Micky Ruiz	Micky Ruiz	Jake Akervik	Clark Moe	5/30/2008	1/31/2010
MPR-6(004)	2009-093 (92329)	Investigation & Evaluation of Closeout Memo Data for the Development of Additional Performance Measures	SP&R	\$83,490	\$26,978	\$10,378	William Bunde	Bill Bunde	Cory Johnson	Clark Moe	1/30/2008	3/31/2010
MPR-6(004)	2009-093 (92724)	Implementation & Closeout Program Administration Support	SP&R	\$39,600	\$18,535	\$9,592	Darlene Gorrill	Darlene Gorrill	Jake Akervik	Clark Moe	4/28/2008	1/31/2010
MPR-6(005)	2007-039 (91515)	Research Management System—Phase I	SP&R/SRP	\$209,000	\$171,200	\$95,200	Archwing Innovations, LLC	Ryan Anderson	Cory Johnson	Cory Johnson	1/2/2008	4/30/2009
MPR-6(005)	2007-039 (94156)	Next Generation of ARTS Tech Support and Maintenance Services	SP&R/SRP	\$19,000	\$10,000	\$0	Archwing Innovations, LLC	Ryan Anderson	Nelson Cruz	Cory Johnson	5/13/2009	4/30/2010
MPR-6(007)	2007-049	Hear Every Voice (HEV) Implementation & Training	SP&R/SRP/Other	\$230,798	\$86,136	\$6,190	University of Minnesota	Jim Grothaus	Scott Bradley	Becky Lein	7/16/2007	5/31/2010
MPR-6(009)	2007-063	TH36 Full Closure Impacts—Highways for Life Corridor: To Close or Not to Close	SP&R/SRP	\$109,890	\$95,605	\$31,868	University of Minnesota	John Hourdos	Chris Roy, Colleen Von-Wagner	Bruce Holdhusen	4/5/2007	1/31/2010
MPR-6(012)	2006-120	Development of New Test Roller Equipment & Construction Specs for Subgrade Compaction Acceptance	SP&R/SRP	\$253,300	\$86,684	\$69,347	Minnesota State University, Mankato	Aaron Budge	Tim Anderson	Dan Warzala	1/24/2008	5/31/2010
MPR-6(014)	2007-032	Evaluation of Safelane Overlay System for Crash Reduction on Bridge Deck Surfaces, Years 2 & 3	SP&R/SRP	\$35,400	\$14,570	\$7,285	University of Minnesota - Duluth	John Evans	Farideh Amiri	Nelson Cruz	2/29/2008	8/31/2010
MPR-6(016)	2007-050	Performance of Thin Unbonded Concrete Overlays High Volume Roads	SP&R/SRP	\$126,100	\$0	\$0	Mn/DOT Office of Materials	Mark Watson	Bernard Izevbehal	Bruce Holdhusen	12/29/2008	2/28/2014
MPR-6(019)	2007-075 (92707)	Technology Transfer Material Development—Phase II	SP&R/SRP	\$99,954	\$99,949	\$78,530	CTC & Associates LLC	Patrick Casey	Cory Johnson	Jake Akervik	4/29/2008	1/31/2010
MPR-6(019)	2007-075 (94094)	Technology Transfer Material Development—Phase III	SP&R/SRP	\$99,203	\$78,040	\$25,572	CTC & Associates LLC	Patrick Casey	Cory Johnson	Jake Akervik	2/24/2009	1/31/2010

Active Single-State SP&R Contracts in 2009, cont.

Study Number	Mn/DOT Tracking Number	Title	Funding Source	Total Project Cost	Total Amount Paid	2009 SP&R Funds Committed	Performing Organization	Primary Investigator	Technical Liaison	Administrative Liaison	Start Date	Projected End Date
MPR-6(019)	2007-075 (95283)	Technology Transfer Material Development—Phase IV	SP&R/SRP	\$99,981	\$3,891	\$0	CTC & Associates LLC	Patrick Casey	Cory Johnson	Jake Akerwik	9/24/2009	4/30/2011
MPR-6(021)	2007-076	Pavement Surface Characteristics Concrete New Construction (MnROAD Studies)	SP&R	\$150,000	\$0	\$0	Mn/DOT Office of Materials	Bernard Izevbekhai	Benjamin Worel	Bruce Holdhusen	12/19/2008	1/1/2013
MPR-6(022)	2006-099	INV 864: Recycled Asphalt Pavements	SP&R/LRRB	\$200,000	\$25,000	\$20,000	Mn/DOT Office of Materials	Eddie Johnson	Roger Olson	Bruce Holdhusen	1/4/2008	12/31/2012
MPR-6(029)	2006-088	INV 868: HMA Surface Characteristics	SP&R/LRRB	\$300,000	\$38,823	\$5,569	Mn/DOT Office of Materials	Timothy Clyne	Greg Johnson	Bruce Holdhusen	9/18/2007	11/30/2012
MPR-6(031)	2007-094	Concrete Pavement Optimization, Determining the Lower Threshold of Slab Thickness for High Volume Roadways	SP&R	\$126,100	\$0	\$0	Mn/DOT Office of Materials	Thomas Burnham	Bernard Izevbekhai	Bruce Holdhusen	1/3/2008	7/31/2014
MPR-6(032)	2007-095	Designing Site-Specific Roadside Prairie or Grassland Seed Mixes	SP&R/SRP	\$125,000	\$85,345	\$49,568	The Kestrel Design Group, Inc.	L. Peter MacDonagh	Kenneth Graeve	Shirlee Sherkow	10/23/2008	3/31/2010
MPR-6(033)	2009-061 (89450-w07)	TRACS Research and Implementation Project	SP&R/SRP	\$310,000	\$246,843	\$158,646	Project Information Services	Tim Malagon	Thomas Wiener	Clark Moe	3/12/2008	6/30/2010
MPR-6(033)	2009-061 (93263)	Construction Project Management Software Evaluations	SP&R/SRP	\$138,697	\$0	\$0	Minnesota State University, Mankato	James Wilde	Thomas Wiener	Clark Moe	9/24/2008	10/31/2011
MPR-8(002)	2008-057	Vehicle Telematics for Novice Teenage Driver Support System—Smartphone Based Novice Teenage Driver Support	SP&R	\$500,000	\$65,284	\$52,227	University of Minnesota	Max Donath	Susan Sheehan	Dan Warzala	12/9/2008	5/31/2011
MPR-8(004)	2008-074	Development of a Concrete Maturity Test Protocol	SP&R/SRP	\$113,952	\$42,720	\$42,720	Minnesota State University, Mankato	James Wilde	Ryan Rohne	Sandy McCully	4/2/2009	9/30/2012
MPR-8(006)	2008-070 (94758)	Anti-icing Technology Implementation	SP&R/SRP	\$99,896	\$15,095	\$15,095	EVS	Paul Keranen	Ferideh Amiri	Bruce Holdhusen	6/12/2009	4/30/2011
MPR-8(006)	2008-070 (94977)	Maintenance Anti-icing Study (Market Research)	SP&R/SRP	\$14,800	\$14,800	\$14,800	Readex Research, Inc.	Jack Semler	Linda Taylor	Bruce Holdhusen	6/19/2009	10/31/2009
MPR-9(001)	2009-117	Stabilized Full Depth Reclamation (SFDR) Implementation	SP&R/SRP	\$25,000	\$0	\$0	American Engineering Testing, Inc.	Dave Rettner	John Hager, Steven Adamsky	Clark Moe	9/18/2009	7/31/2010
MPR-9(002)	2009-159	Concrete Bridge Deck Crack Sealant Evaluation and Implementation	SP&R/SRP	\$80,918	\$4,358	\$4,358	Braun Intertec Corporation	Rachel Detwiler	James Lilly	Dan Warzala	9/30/2009	3/31/2013
MPR-9(008)	2009-182	Mn/DOT's 2009 Peer Exchange—Quantifying and Communicating the Value of Research	SP&R	\$4,635	\$0	\$0	CTC & Associates LLC	Patrick Casey	Linda Taylor	Linda Taylor	10/5/2009	1/31/2010

Active Mn/DOT-Led Multi-State Pooled Funds in 2009

Study Number	Title	Total Project Cost	Total MN Commitment	MN 2009 Commitment	Number of Participating States	Performing Organization	Primary Investigator	Technical Liaison	Administrative Liaison	Start Date	End Date
TPF-5(129)	Recycled Unbound Pavement Materials (MnROAD Study)	\$882,352	\$75,000	\$15,000	6	University of Wisconsin—Madison	Tuncer Edil	Andrew Eller	Nelson Cruz	2007	2011
TPF-5(132)	Investigation of Low Temperature Cracking in Asphalt Pavements, Phase II	\$420,000	\$100,000	\$20,000	7	University of Minnesota	Mihai Marasteanu	Ben Worel	Bruce Holdhusen	2007	2011
TPF-5(134)	PCC Surface Characteristics—Rehabilitation (MnROAD Study)	\$275,000	\$75,000	\$15,000	3	Mankato State University	W. James Wilde	Bernard Izevbekhai	Bruce Holdhusen	2007	2010
TPF-5(148)	Effects of Implements of Husbandry “Farm Equipment”	\$433,000	\$105,000	\$0	6	University of Minnesota	Lev Khazanovich	Shongtao Dai	Bruce Holdhusen	2007	2010
TPF-5(149)	Design and Construction Guidelines for Thermally Insulated Concrete Pavements (MnROAD Study)	\$455,000	\$296,800	\$20,000	5	University of Minnesota	Lev Khazanovich	Tim Clyne	Nelson Cruz	2007	2011
TPF-5(153)	Optimal Timing of Preventive Maintenance for Addressing Environmental Aging in HMA Pavements (MnROAD Study)	\$335,000	\$75,000	\$15,000	6	Mn/DOT Office of Materials	Mike Anderson	Tom Wood	Bruce Holdhusen	2007	2012
TPF-5(165)	Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements	\$360,000	\$60,000	\$0	6	University of Pittsburgh	Julie Vandenbossche	Tom Burnham	Nelson Cruz	2007	2011
TPF-5(171)	Non-Intrusive Traffic Detection Systems III	\$225,000	\$15,000	\$0	13	SRF Consulting Group	Erik Minge	Jerry Kotzenmacher	Deb Fick	2007	2009
TPF-5(190)	Northwest Passage, Phase III	\$200,000	\$25,000	\$25,000	7	Athey Creek Consultants	Dean Deeter	Todd Kramasz	Deb Fick	2008	2009
TPF-5(215)	Transportation Engineering and Road Research Alliance (TERRA)	\$120,000	\$25,000	\$5,000	5	N/A	N/A	Maureen Jensen	Deb Fick	2009	2014
TPF-5(218)	Clear Roads Test & Evaluation of Materials, Equipment and Methods for Winter Maintenance	TBD	\$275,000	\$275,000	12	CTC & Associates	Patrick Casey	Tom Peters	Deb Fick	2009	2011



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