TRANSFORMING PAVEMENT PRESERVATION

Tom Burnham, Minnesota DOT

TOM BURNHAM, JOHN SENGER, AND NATHAN KEBEDE

Burnham is a senior road research engineer with the Minnesota Department of Transportation in Maplewood; Senger is the engineer of pavement technology with the Illinois Department of Transportation in Springfield; and Kebede is the chief operating officer at ARRB Systems in Exton, Pennsylvania.

Above: The smooth rides on durable roadways that Minnesota drivers experience are often a result of research findings discovered at MnROAD, the pavement test track of the Minnesota Department of Transportation (DOT). Despite budget constraints, state transportation agencies are committed to safety, sustainability, and economics—just some of the motivators that drive their quest for new and better ways to preserve pavement.

Transportation agencies across the country know that pavement preservation plays a vital role in maintaining the nation's roadways and highways. Where applied correctly (right material, right pavement, right time), pavement preservation has been proven to extend the life of pavements and provide good returns on investment. Many agencies, however, have struggled to secure adequate funding, identify ideal project candidates, or implement appropriate treatments. Beyond questions about spending money on good looking pavements when so many others are in poor condition, poor project selection and inexperience with often innovative treatments have resulted in early failures that have made it challenging to convince policymakers to continue to invest in preservation activities. Ever constricted budgets—in combination with new federal and state regulations related to addressing environmental concerns—have directed many agencies to rethink how they approach pavement preservation. Whether it is new ways to distribute project funds, innovations in project selection, or new technologies speeding the collection of pavement management data, great strides are being made in this field.

New Paths Forward in Illinois

FUNDING COMES OF AGE

The Illinois Department of Transportation (DOT) officially started its pavement preservation program in FY 2005 with a mandate for each of its nine districts to install three preservation projects that—together—totaled $300,000. The district could choose from one of five treatments: micro surfacing; slurry seal; chip seal; cape seal; and half SMART, a thin (0.75-inch), hot-mix asphalt overlay topped with a chip seal and known as Surface Maintenance at the Right Time. The districts were not given additional funds to cover these projects; therefore, the funding had to come from already constrained budgets. Due to the districts' unfamiliarity with

these treatments and the short length of the projects, these early projects were considered stopgap treatments waiting for the next resurfacing. This meant selected sections were not ideal candidates, and these treatments were not given much room for success.

This situation—with a few minor program changes—continued for three more years before the funding was increased in FY 2015 to $7.5 million, money that was taken off the top of the department's overall program and set aside for pavement preservation. The $7.5 million was then equally divided among the districts to spend on pavement preservation. The original intent of this funding was to develop a committee that would assist the districts in selecting and approving preservation projects. It was not until FY 2018 that the official committee was formed, and the funding was then moved into a competition to select the best candidate projects—regardless of location. The districts saw this as a great way to gain much-needed additional funding for their districts and began taking the project selection process very seriously. The competition continued until FY 2019.

Passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012 required each state transportation agency to create a Transportation Asset Management Plan (TAMP) by June 2019. The creation of Illinois' TAMP changed the way in which Illinois DOT would select and fund its preservation treatments going forward. Development of Illinois DOT's TAMP also required the department to initiate more preservation to maintain their network better.

Pavement preservation treatments were always funded by state monies. However, the increase in use of preservation treatments demanded the expansion of the preservation definition (i.e., allowing additional treatment options), as well as requesting the use of federal funds for these treatments. The Illinois division of FHWA approved the use of federal funds on preservation treatments, but only if they were approved by the pavement preservation committee: a group of experts from the central office, the districts, and the FHWA Illinois division. This created the need for Illinois DOT to develop updated guidance for project selection.

John Senger, Illinois DOT

A yellow line marks the shoulder along a stretch of I-55/US-70 near Collinsville in Illinois. State DOT crews installed the ultrathin bonded wearing course in the summer of 2021. Although the hot-mix asphalt layer is only about 3/4-inch thick, it proves to be a durable surface that extends the life of the well-traveled roadway.

Armed with a new funding source, the department's central office required each district to spend 3 percent of its unrestricted funds on preservation projects (e.g., roads and bridges). Illinois DOT added SMART (1.5-inch hot-mix asphalt overlay with a chip seal wearing course), ultrathin bonded wearing course overlays, diamond grinding, diamond grooving, joint load transfer restoration, hot in-place recycling, joint sealing, and crack filling and sealing to their treatment options. An updated committee—comprised of central office and district representatives—was tasked with reviewing all proposed projects to ensure that treatments were being appropriately selected for the identified roadway sections.

Illinois DOT's central office now had the task of working with the districts to train the agency's personnel, select good projects, and educate the public on this new way of business. The department worked with FHWA, the National Center for Pavement Preservation, consulting engineering firms, and contractors and suppliers in the pavement preservation industry to provide training and updated guidance. The Bureau of Communications within Illinois DOT worked with expert staff and consultants to develop a new communication plan for preservation. The department utilized training from FHWA's Every Day Counts program, the International Slurry Systems Association, and the Midwest Pavement Preservation Partnership to train the agency's personnel on selection, design, and construction of these treatments.

In spring 2019, the Illinois General Assembly—along with support from local businesses, universities, and Illinois DOT—passed the Rebuild Illinois program, as well as a gas tax increase. This program helped grow all the programs within Illinois DOT, including the pavement preservation program. During the 2020 construction season, the department installed 1,220,400 square yards of micro surfacing, 828,600 square yards of cape seals, 1,060,700 square yards of ultrathin bonded wearing course, and 225,237 tons of SMART overlays. All of the preservation in 2020 totaled an awarded price of

$56,330,000. At the end of October 2021, Illinois DOT saw another record year for preservation, with $119,814,000 in awarded projects.

BENEFITS TO THE ENVIRONMENT

Not only is the increased use of pavement preservation projected to save Illinois DOT money in the long run, but these treatments also are better for the environment. Using data presented in *Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements*, a hot-mix asphalt overlay three inches thick produces approximately 15.6 pounds per square yard of greenhouse gases (*1*). By comparison, micro surfacing produces about 0.4 pounds per square yard, cape seals produce 1.1 pounds per square yard, and a SMART overlay would create 9.0 pounds per square yard. Using these numbers to estimate the environmental impact of Illinois DOT's pavement preservation program, a reduction in environmental impact of 65 percent by producing 25.5 million pounds of greenhouse gases is projected, compared with a rehabilitation treatment using 73.8 million pounds. Assuming that Illinois DOT places the first preservation treatment at the appropriate time (while the pavement is still in good condition), historical performance has shown opportunities for a second preservation treatment to be placed, further delaying the need for a rehabilitation treatment and thus saving even more greenhouse gases from being produced.

Figure 1 shows the comparison of greenhouse gases created when using the same amount of square yards placed by Illinois DOT in 2020. The assumed rehabilitation was a three-inch hot-mix asphalt overlay, which is common practice in Illinois. The emulsion-based treatments greatly reduce the greenhouse gases created, and even the SMART overlay reduces the amount by nearly 50 percent.

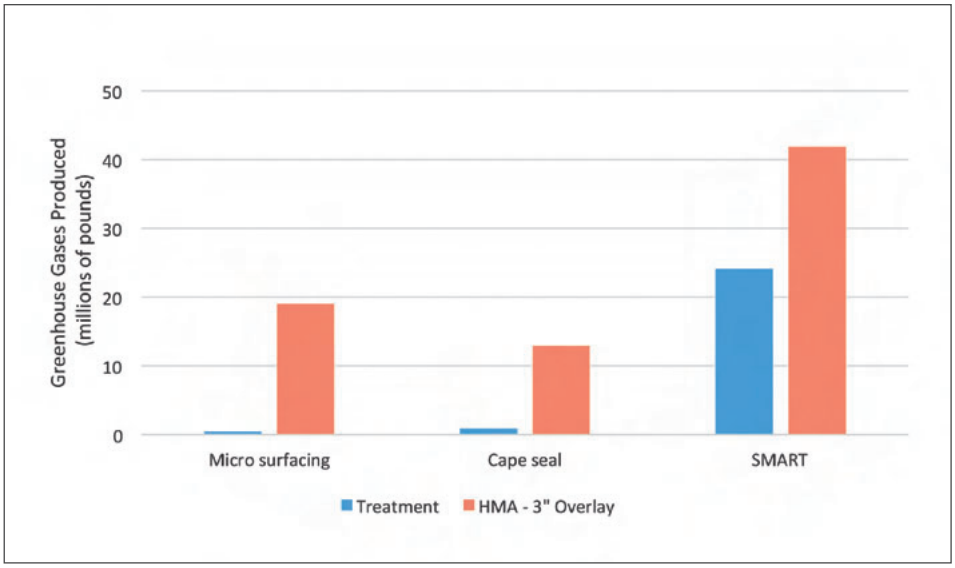

FIGURE 1 Impact of treatment selection on greenhouse gas emissions (HMA = hot-mix asphalt).

A New Recipe in Minnesota

BAKING A NEW PIE

A pastry chef often has to be cognizant of the cost of ingredients when creating a new dessert, as there is a limit to how much customers are willing to add to their final bill. Similarly, public road agencies need to live within their budgets when maintaining their networks. While the Minnesota DOT has a plethora of methods to maintain their roads, constrained budgets in the past decade have resulted in choosing to cover more miles with lower cost solutions than investing in longer term fixes. Without a mix of fixes, a pavement network will eventually decline to a point where lower cost repairs are no longer feasible. To address this situation, Minnesota DOT recently updated their method of selecting pavement rehabilitation and maintenance projects.

As a state agency, Minnesota DOT is responsible for maintaining the Interstate highway, U.S. highway, and state highway portions of the pavement system in Minnesota. It also provides financial aid and technical support to county, city, and local agencies. Minnesota's geographical location at the center of the continent results in pavements exposed to some of the most extreme weather conditions in the lower 48 states. Annual air temperatures range from –60°F to 100°F. Therefore, the condition of pavements is strongly impacted by environmental response and material durability. Minnesota DOT has always invested in and been a leader in seeking the latest in pavement technology, as demonstrated by their 30-year ownership and operation of the MnROAD pavement testing facility (*2*).

Tom Burnham, Minnesota DOT

A patchwork of concrete pavement and asphalt subsurface reveal experimental repairs of an ultrathin concrete overlay at the MnROAD facility near Albertville, Minnesota. For more than 30 years, Minnesota DOT has performed innovative pavement research on numerous test tracks and offsite locations.

Using the latest in pavement design, construction, and maintenance techniques, Minnesota DOT prides itself on maintaining their pavement system in good overall condition, despite the challenging climate conditions. However, adopting new technologies is not always enough to meet pavement performance targets, and decades of working under constrained budgets has led to less diversification in the selection of pavement repair and maintenance treatments. And, as shown in Table 1, pavement rehabilitation and maintenance of the system far outweigh construction of new routes.

To guide pavement activities, Minnesota DOT has maintained a robust pavement management system for many decades. Pavement condition surveys are conducted annually and used to update pavement selection procedures frequently. Since 2011, pavement type selection within new construction, rehabilitation, and maintenance projects has been primarily based on life-cycle cost-assessment procedures aimed at optimizing the lowest-cost alternative among those with equal benefits. In addition, funding for preventive maintenance treatments for pavements was covered under separate budgets, which were often diverted to cover other department priorities. Operating under this system worked well for a while. However, more recently, it has resulted in a substantial increase in shorter lived and less diverse types of pavement fixes. When managing a pavement network, it is ideal to have a similar population of projects across various conditions and ages, such that a large group of poor-condition pavements are not due for repairs or replacement at the same time. Several years ago, Minnesota DOT recognized that it needed a different approach to project selection to maintain a cost-effective pavement system in good condition.

Tom Burnham, Minnesota DOT

A road repair crew retrofits dowel bars into existing concrete pavement on the MnROAD Low-Volume Road. Placed across pavement joints, such installations extend the life of the pavement.

TABLE 1 Distribution of Minnesota DOT Pavement Activities from 2016 to 2020

Pavement Activity	Percentage of Project Miles
New/Reconstruction	6.5
Recycling	14.0
Asphalt Overlay	52.9
Concrete Overlay	8.1
Concrete Repairs	2.8
Maintenance	15.6

New performance metrics invoked by FHWA under MAP-21 guidelines coincided with the development of Minnesota DOT's new pavement type selection system (*3*). This quickly turned efforts toward developing a system that could meet the department's and FHWA's criteria. Instead of a primary focus on life-cycle cost assessment evaluations, the new procedure now aims toward a balance of three principal measures: ride quality, cost, and diversity of fixes. Meeting ride-quality metrics not only serves Minnesota pavement users better, but it also satisfies FHWA's recent requirements. Since budgets are expected to remain constrained for some time, project costs will now be evaluated for how they meet a measure defined as the asset sustainability ratio. Finally, Minnesota DOT districts will be strongly encouraged to

diversify their projects toward investment in a number of longer lived pavement selections and preventive maintenance treatments, resulting in a mix of fixes.

To satisfy each of these three criteria, Minnesota DOT worked with Stantec to develop an analysis tool to enable such assessments. Called the "Pavement Investment Evaluator" or "PIE," this software allows pavement designers and planners to more easily run pavement type selection and treatment scenarios with a given budget, while meeting the following eight pavement health indicators:

- Ride-quality index condition,
- Ride-quality index per vehicle miles traveled,
- Ride-quality index needs backlog,
- Asset–Sustainability ratio,
- Life category of treatment,
- Remaining service life range,
- Asset valuation, and
- Network costs ($, $/lane-mile and $/ESAL-lane-mile).[1]

Not yet ranked in any particular order of importance, these measures are designed to examine how and where funding is spent on a long-term and networkwide basis, not just project by project. Implementation of the new pavement selection procedure and PIE tool is currently underway, including refinement of comprehensive user manuals and training modules. Further information will be available soon on the Minnesota DOT Pavement Management website: http://www.dot.state.mn.us/materials/pvmtmgmt.html.

[1] Equivalent single-axle load (ESAL) is a historically accepted measure of traffic loading used during pavement design.

BENEFITS FROM COMPETITION

While Minnesota DOT envisions that its new procedure for pavement project selection will lead to maintaining or improving the overall condition of the statewide pavement system, another expected benefit is an increase in the competition between the concrete and asphalt paving industries. In recent years, multiple studies have demonstrated that increasing the number of opportunities for competitive bidding often results in overall lower costs from both industries, thus benefiting Minnesota taxpayers (*4*). An increase in the number and diversity of projects also incentivizes local paving contractors to invest in new equipment and train personnel, ultimately improving the quality of the pavements they construct and rehabilitate in Minnesota.

Improved Project Scoping

COMPREHESIVE EVALUATION WITH TRAFFIC SPEED DEFLECTION DEVICES

Traffic speed deflection devices, commonly referred to as TSDDs, are pavement evaluation equipment that measure roadway pavements' structural capacity or bearing capacity. While older pavement structural capacity measurement tools—such as the falling weight deflectometer (FWD)—are stationary testing devices, TSDDs operate at traffic speeds. These devices collect continuous data and can operate at speeds between five and 60 miles per hour, resulting in daily data collection rates of up to 300 miles. Therefore, TSDDs present a more effective and productive option for transportation agencies to gather large amounts of pavement condition data quickly. Various investigations and research studies have been undertaken in the United States, Europe, Australia, and South Africa to establish the relationship between TSDD data and FWD data. A Virginia Transportation Research Council study found that TSDD measurements yield similar and more consistent results in identifying structurally deficient sections of roads when compared to FWD (*5*). TSDD-measured deflections also have been verified using FWD measurements (*6*).

To make data collection even more cost effective and productive, some equipment manufacturers have developed TSDDs that capture additional roadway information such as cracking, roughness, and subsurface data. The iPAVe (intelligent pavement assessment vehicle) is one such advanced TSDD that measures additional roadway data.

Transportation agencies' primary motivation for adopting TSDD through

Courtesy of ARRB Sytems

Ready to roll with the flow of traffic, this intelligent pavement assessment vehicle—or iPAVe—is a TSDD. Using sensors on the back and the rear axle, this particular vehicle has collected data on roadway pavement functional and structural capacity for more than 25 Idaho transportation agencies.

the use of the iPAVe is the ability to perform comprehensive pavement evaluations by collecting all pertinent roadway condition data simultaneously. This also allows them to consume the data at the same time. Analyzing complete data has been proven to lead to more informed decisions when compared with looking at single data streams. One of the significant impacts of TSDD data has been pavement construction project selection. With access to comprehensive data from TSDD, transportation agencies can confidently identify ideal candidates for pavement preservation and rehabilitation activities. TSDD data enable agencies to consider the surface and structural condition of pavement sections so that pavement managers and designers are aware of scenarios where surface conditions appear good while structural conditions are poor, or where surface conditions appear bad while the sections are structurally sound. The following are case examples for three state transportation agencies that are currently utilizing TSDD data.

New Mexico With a population of 2.1 million and more than 27,000 miles of pavement, New Mexico is one of the leading states in collecting TSDD data and exploring applications for the data. New Mexico started collecting TSDD data in 2019 and has increased the collection efforts annually. The state is on track to collect more than 4,500 miles of TSDD data by the end of 2022. New Mexico DOT considers the TSDD as another tool in their toolbox for collecting actionable data on the condition of the state's roads. The department has a $20 million annual budget for pavement preservation, and it expects to better identify appropriate preservation candidates through the use of TSDD data. Accurate identification of preservation candidates will lead to long-lasting pavement preservation projects, which results in a high return on investment for New Mexico taxpayers. Although New Mexico also uses TSDD data for design–build projects, one of their top priorities is accurately identifying pavement preservation projects and appropriately designing preservation applications.

Idaho Having started data collection as early as 2017, Idaho is one of the earliest states to adopt TSDD data. Since 2018, the state has collected more than 4,800 miles of TSDD data. A study conducted for the Idaho Transportation Department showed that preservation and rehabilitation decisions made with TSDD data have a return on investment of more than 700 percent over the life of the pavements (*7*). Based on this study, the Idaho Transportation Department is taking steps to calculate a TSDD–based "remaining life" index of its pavement sections to populate the state's pavement management system.

Texas With more than 100,000 miles of pavement, Texas routinely looks for better ways of managing and maintaining the state's vast roadway infrastructure. Texas is part of a TSDD Pooled Fund Study (administered by FHWA) and has collected close to 3,000 miles of TSDD data throughout the state. It is one of the leading states in implementing TSDD data into their state pavement management system, with various districts now making pavement preservation and rehabilitation decisions based on the information. Texas relies heavily on pavement preservation treatments (such as chip seals), and the state expects its use of TSDD data for project selection to help identify roads that can gain long-term benefits from these treatments.

IMPROVED DECISIONS

Innovative technologies like TSDD play a critical role in supplying accurate data needed to make more informed decisions. Not only do TSDDs provide comprehensive data, but their use in decision making for pavement preservation and rehabilitation has been proven to produce positive returns on investment. The continuous and comprehensive data collected by TSDDs like the iPAVe enable state DOTs and practitioners to effectively and accurately filter structurally sound pavements as perfect candidates for pavement preservation treatments. Alternatively, the data also can filter out structurally poor pavements so that state DOTs do not waste pavement preservation funds on sections not best suited for preservation. As more transportation agencies use TSDD data on a routine basis, the demand for—and reliance on—pavement preservation applications is expected to increase significantly.

The Path Forward

With the maturing of the U.S. roadway system, the focus of transporation agencies is now very much directed toward pavement preservation. Recognition that preventive maintenance treatments are an effective way to increase returns on investment is transforming the way agencies are doing business. New technologies will continue to enable better project and treatment selections, and efforts to incorporate sustainable practices will continue to evolve. In the end, the overall winners will be the taxpayers and traveling public.

REFERENCES

1. Galehouse, L., and J. Chehovits. Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements. *Compendium of Papers from the First International Conference on Pavement Preservation*, 2010, pp. 27–42.
2. MnROAD. MnROAD: Minnesota's Cold Weather Pavement Testing Facility. 2021. http://www.dot.state.mn.us/mnroad/.
3. Cornell Law School Legal Information Institute. National Performance Management Measures for Assessing Pavement Conditions. FHWA, U.S. Department of Transportation, 2021. https://www.law.cornell.edu/cfr/text/23/490.307.
4. Mack, J. W., L. G. Wathne, and F. Mu. Improving Network Investment Results by Implementing Competition and Asset Management in the Pavement Type Selection Process. *Proceedings of the 11th International Conference on Concrete Pavements*. International Society for Concrete Pavements, San Antonio, Texas, 2016.
5. Katicha, S., S. Shrestha, G. Flintsch, and B. Diefenderfer. *Network Level Pavement Structural Testing with the Traffic Speed Deflectometer.* Virginia Transportation Research Council, Charlottesville, 2020.
6. Abohamer, H., M. Elseifi, Z. U. A. Zihan, Z. Wu, N. Kebede et al. (2021). Development of an Artificial Neural Network–Based Procedure for the Verification of Traffic Speed Deflectomter Measurements. *Transportation Research Record: Journal of the Transportation Research Board,* No. 2675, 2021, pp. 1076–1088. https://doi.org/10.1177/03611981211005774.
7. Maser, K., P. Schmalzer, A. Gerber, and J. Poorbaugh. Implementation of the Traffic Speed Deflectometer (TSD) for Network Level Pavement Management. Presented at Virginia Tech Transportation Institute, 2019. https://www.vtti.vt.edu/PDFs/PE-2019/Maser2.pdf.