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APPROPRIATE IMPLEMENTATION OF PAVEMENT PRESERVATION TREATMENTS

FINAL REPORT
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16. Abstract This research conducted an extensive literature search of national, state, and industry pavement preservation and rehabilitation centers' libraries for applicable treatments (pavement preservation, rehabilitation, and reconstruction) that New Jersey DOT could use on their high volume state-maintained roads. Reports in PDF format were collected and stored in an Access database to allow easy searches by DOT staff.

A survey of all state DOTs was conducted to determine their use of these treatments. Fourteen states responded. The survey is summarized in volume 2 of this report. Our research partner, Deighton Associates conducted a survey and interviews of the state DOT contacts that use dTIMS PMS software. A review of their PMS database identified what treatments were used, the treatment's trigger, condition reset, life extension and costs. Summary tables are listed in this report.

Based on the literature search and survey results, NJDOT selected seven treatment types that could be used in NJ. These included Fog Seal, Slurry Seal, Micro-Surfacing, Chip Seal, Cold In-place Recycling-Foamed Asphalt, Cold In-place Recycling-Asphalt Emulsion, and Hot In-place Recycling.

Material and construction specifications, test methods (mix design, where applicable) and usage guides were developed. These are provided in volume 2.

This research also summarized the effect of available suppliers and contractors on implementation. Some states limit the use of certain treatments based on the availability of contractors in their state. Demonstration projects which included CIR, FDR, Asphalt Rubber Chip Seal, Slurry Seal and Micro-surfacing treatments provided training opportunities for NJDOT staff.

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EXECUTIVE SUMMARY

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BACKGROUND

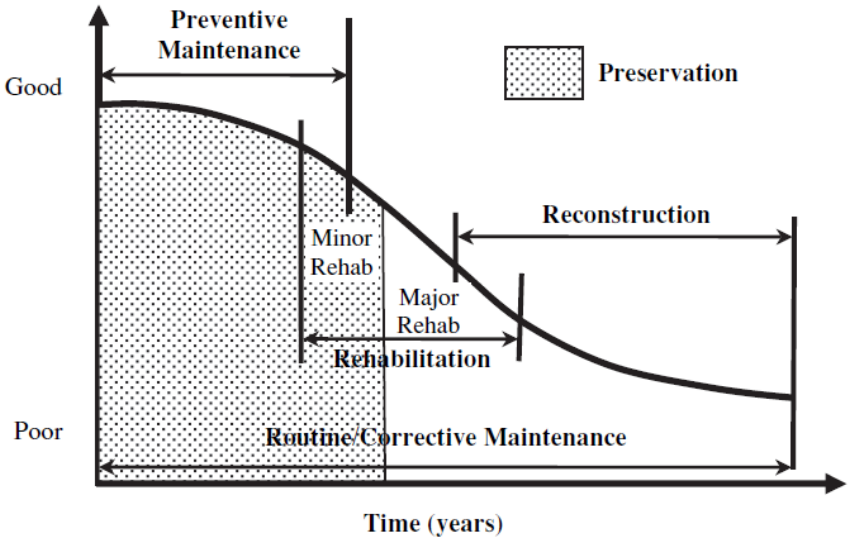
The New Jersey Department of Transportation (NJDOT) recently formed a Pavement Preservation Task Force and added Pavement Preservation Treatments to the Department's Pavement Management System (dTIMS). The Department would like to expand its use of pavement preservation treatments and newer pavement rehabilitation and reconstruction treatments to extend pavement service life and move away from a "Worst-Case" pavement selection methodology and utilize the most cost effective selection of appropriate treatment to expand the available pavement funding. Currently NJDOT staff does not have broad experience with many of the pavement preservation treatments on the market and many treatments have been improved since the NJDOT's last experience with them. NJDOT sought assistance in identifying treatments that will have a high success rate on NJ's state-maintained roads, shoulders and ramps, taking into consideration the climate, pavement type and condition, traffic levels and loading, construction staging practices and constraints on local materials, suppliers and contractors. The NJDOT asked that the research add Hot and Cold In-place recycling as an alternative rehabilitation treatments and Full Depth Reclamation as an alternative reconstruction treatment.

Pavement preservation has been defined by FHWA as, "a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations."[1] The critical features of a pavement preservation program are choosing the right treatment on the right road at the right time. This research study examined the pavement preservation treatments that are appropriate on NJ's state-maintained roads, the means of selecting the right time and condition to apply the treatment, the treatment's effectiveness on the road's condition, and the extension of the service life and the cost of applying the treatment.

The current methods for addressing deficient pavement sections fall into three primary categories.

- Pavement preservation treatments to preserve or improve fair and good pavements to good condition without enhancing the pavement structure,
- Rehabilitation treatments that restore pavements to like-new condition, and
- Reconstruction treatments used to replace the pavements that have exhausted its useful life.

Figure 1 shows different categories of pavement treatments applied at different stages of pavement conditions.



Source: Adapted from Peshkin et al. 2007.

Figure 1. Different categories of pavement treatments applied at different stages of pavement conditions

An effective pavement preservation program will address pavements while they are still in good or fair condition; before the onset of serious damage. By applying a cost-effective treatment at the right time, the pavement is sealed to prevent moisture infiltration or restored to almost its original condition. The cumulative effect of systematic and successive preservation treatments is to postpone costly rehabilitation and reconstruction. During the life of a pavement, the cumulative discounted value of the series of pavement preservation treatments is generally more economical than the cost of major rehabilitation and substantially less than the more extensive, higher cost of reconstruction. Additionally, performing a series of successive pavement preservation treatments during the life of a pavement is less disruptive to uniform traffic flow than the long closures normally associated with reconstruction projects.

Considering that a pavement's worst enemy is water, the key role of pavement preservation treatments is to minimize the infiltration of water, and improve pavement condition and safety, at a minimum cost. Unlike pavement rehabilitations and reconstructions, pavement preservation treatments provide little or no increase in structural strength.

During the 1990's, Congress incrementally broadened, through legislation the applicability of Federal-aid funding to preventive maintenance and preservation activities. Congress' acknowledgement of preventive maintenance activities as an eligible activity on Federal-aid highways is a logical step that reinforces the importance of implementing a continuing preventive maintenance program.[2]

Based on a FHWA memorandum, "Pavement preservation represents a proactive approach in maintaining our existing highways. It enables state transportation agencies

to reduce costly, time consuming rehabilitation and reconstruction projects and the associated traffic disruptions. With timely preservation, we can provide the traveling public with improved safety and mobility, reduced congestion, and smoother, longer lasting pavements. This is the true goal of pavement preservation, a goal in which the FHWA, through its partnership with States, local agencies, industry organizations, and other interested stakeholders, is committed to achieve." [3]

A Pavement Preservation program consists primarily of three components: preventive maintenance, minor rehabilitation (nonstructural), and some routine maintenance activities as seen in Figure 2.

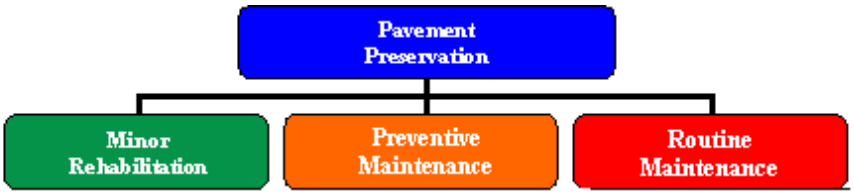


Figure 2. Components of Pavement Preservation

An effective pavement preservation program can benefit State Transportation Agencies (STA) by preserving investment on the NHS and other Federal-aid roadways, enhancing pavement performance, ensuring cost-effectiveness, extending pavement life, reducing user delays, and providing improved safety and mobility. The actions taken by Congress and the US DOT led to the expansion of funding for preventive maintenance and pavement preservation activities with federal funding.

AASHTO TSP^2 Transportation System Preservation Technical Services Program promoted the Northeast Pavement Preservation Partnership (NEPPP) which provides a forum for state transportation professionals and other partners in the Northeast states to collaborate on the development and implementation of pavement preservation treatment techniques and specifications for states with similar climatic conditions. Figure 3 provide an illustration of the partnership and the Pavement Preservation Partnership areas.

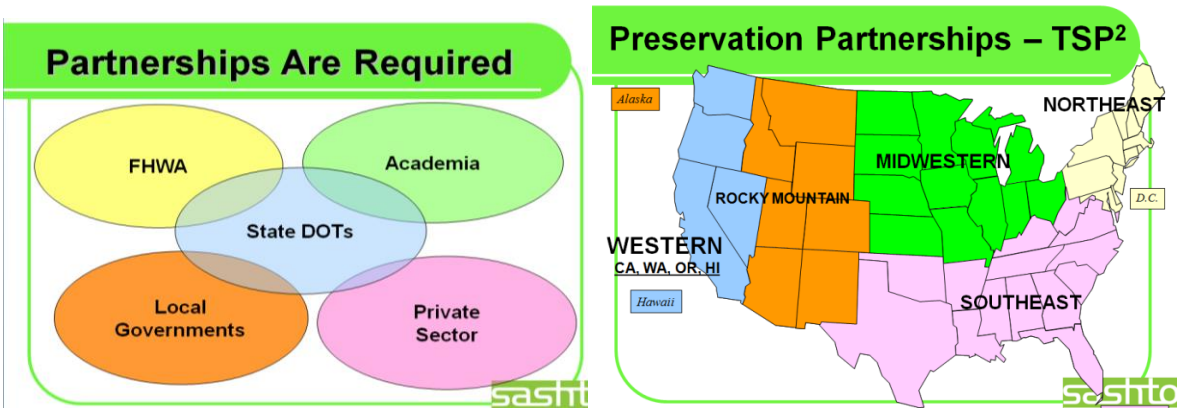


Figure 3. Preservation Partnerships

New Jersey is not alone in their desire to expand the pavement preservation and rehabilitation tool box. The pavement preservation philosophy has seen increased adoption in State Departments of Transportation (DOTs) across the United States as a result of the successful educational and outreach programs and availability of federal funding instituted by FHWA and other pavement preservation organizations over the past decade.[3] The fact remains that the effectiveness of pavement preservation activities has not been well documented or publicized throughout the United States. These activities have prompted recent studies by FHWA, NCHRP, SHRP-2, other Pavement Preservation Centers and other State agencies that were identified and summarized in this research to achieve an expansion of the NJDOT pavement tool box in the pavement preservation area.

While pavement preservation treatments have been available and used on pavements for many years, these treatments, until recently, have been restricted by the agency staff to lower volume roads with less traffic than was expected to exist on State level facilities. Several transportation agencies apply preservation strategies on lower-volume roadways; however, the application of these strategies on high-volume roadways has lagged behind.

In 2011, SHRP-2 Renewal Project R26 developed guidelines on pavement preservation strategies for high-traffic-volume roadways that can be implemented and used by public agencies. [4,5] The SHRP-2 Renewal Project included an extensive literature search and review to identify practices and experiences relating to preservation of high-traffic-volume roads. DOTs have different definitions regarding what constitutes a high-traffic-volume roadway, ranging from an average daily traffic (ADT) as low as 1,000 vehicles per day (vpd) to as high as 100,000 vpd. This study defined high traffic volume as an ADT of at least 5,000 and 10,000 vpd for rural and urban roadways, respectively. The focus of this research was to identify potentially successful techniques for pavement preservation approaches on high volume road that are not yet fully deployed and challenges and solutions to implementat these treatments on high-traffic volume roadways.

The most notable conclusions are the following:
• Several preservation treatments are currently being extensively used or have been documented as successfully used on high-traffic-volume roadways.
• Successful selection of projects and preservation treatments for high-traffic-volume roadways requires that:
- ✓ Treatment functions be properly matched to pavement conditions;
- ✓ Potential effects of traffic level and climatic conditions on expected treatment performance be properly assessed;
- ✓ Project construction constraints be carefully examined in relation to the limitations of the treatments; and
- ✓ Treatment cost-effectiveness and other factors be properly and methodically considered.

The study included a comprehensive survey of preservation practices to obtain information on current preservation practices for hot-mix asphalt (HMA) and Portland cement concrete (PCC) surfaced pavements on high-traffic-volume roadways in rural and urban settings and detailed guidelines on pavement preservation strategies using the state of the practice and a comprehensive treatment selection framework and process. The purpose of this report was to provide guidance for matching the pavement condition and other considerations more effectively with suitable treatments for high-traffic-volume roadways.

Factors Affecting Project and Treatment Selections for Pavement Preservation

- Traffic Level
- Pavement Condition
- Climate/Environment
- Work Zone Duration Restrictions
- Expected Treatment Performance
- Costs

Table 1 provides a list of States and Canadian Provinces that responded to this SHARP 2 survey

Table 1. State Highway Agencies and Canadian Provinces

Alaska	**Kansas**	**New Mexico**	**Virginia**	**Hawaii**	**Canadian Provinces**
Arizona	**Kentucky**	**New York**	**Washington**	**Illinois**	**Alberta**
Arkansas	**Louisiana**	**North Carolina**	**Wisconsin**	**Indiana**	**British Columbia**
California	**Maine**	**Ohio**	**Wyoming**	**Iowa**	**Manitoba**
Colorado	**Minnesota**	**Oklahoma**	**Montana**	**South Dakota**	**New Brunswick**
Connecticut	**Michigan**	**Pennsylvania**	**Nebraska**	**Tennessee**	**Ontario**
Florida	**Mississippi**	**Rhode Island**	**Nevada**	**Texas**	**Quebec**
Georgia	**Missouri**	**South Carolina**	**New Hampshire**	**Utah**	**Saskatchewan**

A few states and universities have formed Pavement Preservation Centers to provide much needed information on pavement preservation treatments, their appropriate application, treatment selection, life extension, and costs. The National Center for Pavement Preservation at Michigan State University and the Foundation for Pavement Preservation, formed in 2003, have provided a focus for pavement preservation information throughout the county. The Texas Pavement Preservation Center and the California Pavement Preservation Center were formed with state funding to provide pavement preservation information for agencies. A complete list of pavement preservation centers is provided in Volume 2 - Appendix 2.

In addition, efforts of the International Slurry Surfacing Association (ISSA), the Asphalt Recycling & Reclaiming Association (ARRA), the Asphalt Institute (AI), National Concrete Pavement Technology Center at Iowa State University, Coalition to Preserve America's Roads, American Public Works Association (APWA), National Asphalt Pavement Association (NAPA), and American Concrete Pavement Association (ACPA) have improved the information, education and training of the pavement preservation and rehabilitation industry suppliers and contractors and provided an expansion of information that can be used by government agencies.

The New Jersey Department of Transportation is also interested in better utilizing its pavement management system to identify appropriate locations for specific pavement preservation treatments based on the traffic level and pavement condition data (IRI, Surface Distress, Rutting, etc.) that the Department currently collects. This research involved identifying the correct pavement age and/or condition triggers for each

pavement preservation treatment in order to select the appropriate preservation treatment for the appropriate pavement locations at the correct age.

RESEARCH OBJECTIVES

The objectives of this research study were to:

- Develop a list of appropriate pavement preservation treatments for use on HMA, Composite and PCC pavements on the NJDOT state-maintained road network
- Develop NJDOT Specifications for each Pavement Preservation Treatment
- Document the Constraints on Pavement Preservation Treatments on Suppliers and Contractors availability
- Develop and Facilitate Pavement Preservation Treatment Training and Implementation

To achieve the objectives, a team was formed with diverse expertise in pavement management system and pavement preservation treatment from Rutgers University, and industry experts on pavement management systems from Deighton Associates Limited. The team included experts with practical and theoretical expertise, as well as implementation expertise with the NJDOT's current PMS software, to ensure the results were in a format that could be directly implemented.

Introduction

The research addressed the needs of the NJDOT concerning the development and implementation of pavement preservation treatments applicability for the state-maintained road in NJ. The research team explored the various aspects of the pavement preservation treatment topics to summarize the state-of-the-art in the pavement preservation area for the various units within the NJDOT. The research refined the current pavement management system inputs concerning the pavement preservation treatments, developed NJDOT specifications and construction procedures for the various pavement preservation treatments, assessed the effects of constrained availability of pavement preservation treatment material suppliers and contractors on the pavement preservation program and facilitated the training and implementation within New Jersey.

Literature Search

The Literature search focused on pavement preservation treatment descriptions and their current uses and limitations to develop an appropriate list of treatments that will have a high success rate for use on HMA, composite and PCC pavements sections on the state-maintained roads in New Jersey. The Literature Search identified Pavement Management System inputs for pavement preservation treatments, treatment

specifications, construction procedures, and treatment costs. The Literature Search collected reports in digital format (PDF) files of each report and included them in an Access database with search capabilities.

The Literature Search included a thorough examination of the following information sources:

- FHWA, FHWA Resource Centers, Turner Fairbank Highway Research Center, AASHTO, TRB papers and presentations, NCHRP reports and syntheses, LTPP SPS3 and Datapave, SHPR2, Pavement Preservation Conference presentations
- Pavement Preservation Centers (National Pavement Preservation Center, California Pavement Preservation Center, Texas Pavement Preservation Center, Illinois Pavement Preservation Center, etc.),
- Industry sites (International Slurry Surfacing Association, Asphalt Recycling and Reclaiming Association, Foundation for Pavement Preservation, Asphalt Institute),
- National Association of County Engineers, New Jersey Society of Municipal Engineers.

The research team reviewed reports, presentations, manuals, and conducted phone interviews with agencies to collect the necessary information from these national, state, and industry sources.

Literature Search Summary

Types of Preservation Treatment

Preventive maintenance or preservation is a cost-effective activity applied at relatively early stage of pavement service life. Table 2 presents the basic performance of several preventive treatments. [1,2,3,4,5,6,7,8,9,10,11] Those treatments can improve pavement functional performance, retard certain distress development, and reduce deterioration rate.

Effectiveness of Pavement Preservation Treatments

This section summarizes previous findings on the effectiveness of preservation treatments with a focus on four treatments: crack seals, slurry seals, chip seals, and thin overlay. These findings are organized respectively for each type of treatment.

REPORT S2-R26-RR-1 Preservation Approaches for High-Traffic-Volume Roadways, SHRP2, 2011 [4,5] provides a comprehensive summary of the pavement preservation techniques used throughout the county.

Table 2. Summary of Major Preventive Treatments

Preventive Treatment	Description	Characteristic	Typical Life Extension	Cost (1000$/ per lane mile)
Fog Seals	A light spray (typically 0.05 to 0.15 gal/yd^2) of a diluted asphalt or rejuvenator emulsion	Delay further oxidation, weathering and raveling, provide edge-shoulder delineation	1-2	2.4-3
Slurry Seals	Mixture of emulsion asphalt and well-graded aggregate with surface thicknesses of 10 to 20mm	Provide skid resistance, perform best in warm-weather climates	3-6	7-11.5
Chip Seals	Sprayed with asphalt and then immediately covered with aggregate and rolled	Seal small cracks, wearing course on low-volume roads	4-6	7-12.5
Micro-surfacing	Mixture of polymer-modified emulsion, mineral filler and dense-graded crushed fine aggregate, surface thicknesses range 10 to 20mm	Cure in less than one hour, fill rutting, and provide surface friction, seal crack, can be applied on pavement with poor condition	4-7	15-24
Thin Overlay	HMA with thicknesses of 13 to 38mm	Restore pavement ride quality	4-10	20-35
Not Selected by NJDOT For Further Investigation				
Crack Seals	Crack preparation followed by the placement of a high-quality asphalt material	Prevent the intrusion of water	1-2	1.5-2.5
Sand Seals	Emulsion asphalt with broom scrubbing followed by application of small aggregate with second brooming, thicknesses range from 6mm to 10mm	Fill air voids, surface narrow cracks, rejuvenate the oxidized asphalt and poor friction	3-4	5-8
Flush Seals	Application of sprayed film of emulsion bituminous binder followed by light covering of fine aggregate	Seal pavement surface and prevent infiltration of water	2-5	6-15
Cape Seal	Chip seal covered by a slurry seal or a microsurfacing	Provide a smooth, dense surface, good skid resistance and reduce noise	6-10	12-20

Crack Seals

Crack sealing is always the first line of defense in pavement preservation though it does not show significant improvement in long-term performance. Cohesion loss, adhesion loss and edge deterioration contributed highly to the overall failure in some crack seal treatments. Modified rubberized asphalt sealant may show long-term crack-seal performance (5-8 years).[12]

Crack sealing may provide the most cost-effective use of dollars over time in certain existing pavement condition compared to other pavement maintenance techniques. A study based on Pennsylvania local roads program concluded that roadways applied with crack seals have better ridability five years later than other surface treatments, such as chip seals, thin overlays and slurry seals.[13] A research study used the data collected from 14 LTPP SPS-3 sites in Texas and investigated the effectiveness of four preventive maintenance treatments (crack seals, slurry seals, chip seals, and thin overlay). It was found that crack sealing was the best among the four preventive maintenance alternatives for low traffic routes with a sound underlying pavement structure.[14]

Yildirim, et al. concluded from their survey and field study results indicate that hot pour sealants performed better than cold pour sealants. In addition, hot pour sealants had lower average annual cost values than cold pour sealants.[15]

Slurry Seals

Eltahan et al. assessed the performance of each treatment in LTPP SPS-3 sections using survival analysis and a median survival time was computed as the number of years until 50 percent of the treatment sections fail. The median survival times for thin overlay, slurry seal, and crack seal were found 7.0, 5.5, and 5.1 years respectively.[16] A recent study based on the observed roughness data in the LTPP SPS-3 sections found that the approximate life extension of the pavement sections benefiting from preservation treatments is: thin overlay for 5.4 years, chip sealing for 1.9 years, crack sealing for 1.7 years, and slurry sealing for 1.1 years.[17] Those results demonstrate the relative low effectiveness of slurry seal in maintaining ride quality.

Specific findings from the 5-year evaluation of slurry seals under the LTPP SPS-3 study indicate that slurry seals perform better in warmer climates.[18] Peshkin et al. concluded that slurry seals have some influence on long-term roughness and rutting. They suggested that slurry seal should not be placed on pavements with moderate or severe cracks, or progressive rutting.[22]

Chip seals

High performance of chip seals are documented by extensive previous studies. Carvalho et al. analyzed the LTPP SPS-3 sites and found that the performance of chip seal was superior to thin overlay in freezing temperature zones, wet climates, and pavements with coarse subgrade.[19] A SPS-3 study using Texas sites found that chip seals performed well on a wide range of pavement conditions, and for most sites, was rated as the best treatment.[16] Shirazi et al. conducted a statistical analysis to compare the performance effectiveness of each treatment and concluded that the thin overlay and chip seal treatments were first options with respect to fatigue cracking.[20] A Study conducted in Minnesota also discovered that chip seals may outlast thin overlay. It is forgiving and did not reflect the cracking that existed before the treatment applications.[21]

The performance of chip seal is also sensitive to a variety of factors. Peshkin et al. concluded that the performance of chip seal in deep freeze zone is better than the performance in moderate freeze and no freeze zone.[22] Michigan DOT's experience shows that chip seal may have poor performance under moderate to heavy commercial traffic because of aggregate loss and flushing. It points out that chip seal may result in a very rough surface that leads to significantly louder rolling noises of vehicle wheels.[23]

In a study to compare emulsion based and Hot Asphalt Chip Seal, Gransberg, found that the emulsion chip seals performed as well as the hot asphalt cement seals and were the more cost effective of the two alternatives. Emulsion chip seals also furnished a better long-term friction course as measured by the skid number.[24]

Thin Overlay

Studies proved the outstanding performance of thin overlay. A FHWA sponsored study in 1998 investigated the LTPP SPS-3 test sections based on surveys from Expert Task Groups (ETG) and analyzed the data from the LTPP database. The results concluded that the best performance with respect to cracking was found in the thin overlay and chip seal sections. A comprehensive NCHRP study was conducted in 2000 to analyze the data from all the LTPP SPS-3 sites.[25] The study found that the thin overlay was the only one to demonstrate a significant initial effect on rutting.

A study conducted in Delaware suggests that the increased severity of either weather or traffic effect is sufficient to cause a drastic reduction in the treatment service life in thin overlay. The wide range of service life of thin overlay treatments is strongly depending on levels of weather severity, traffic, and route type. The service life of thin overlay is approximately 3 to 13 years when IRI is used as the performance indicator, 3 to 14 years for rutting, and 3 to 24 years for Pavement Condition Rating (PCR).[26]

Since the HMA thin overlay significantly improves pavement condition with a relatively high cost, a study by Dong suggested that microsurfacing could be a more cost-effective treatment. It is concluded that the cost-effectiveness of preservation decreases with the increase of traffic level and pre-treatment pavement deterioration.[8]

Factors Affecting Effectiveness of Preservation

Many factors contribute to the selection of an optimal treatment for an existing pavement. The factors may include existing pavement life, geography, distress severity, traffic levels, predetermined timetable, and available funding. For example, when a preventive treatment is applied, a pavement in relatively poor condition may receive higher performance jumps but higher deterioration rate.

A survey conducted by NCHRP project 20-07 in the US found that the five main purposes of preventive maintenance are: reducing rate of deterioration, sealing surface, reducing water infiltration, increasing friction and smoothness. Most of the state agencies apply preventive treatments when the pavement is in the good and fair categories, but there are also some surprising responses: one agency reports that 60 percent of their treatments are placed on pavements in very good condition, while nine agencies report placing at least 30 percent of their preventive maintenance treatments on pavements in poor or very poor condition.[27] Some of these can be considered a stop-gap procedure to maintain the pavement in useable condition until a more permanent fix can be applied.

Performance and effectiveness of pavement preservation techniques may highly depend on the local traffic and climate conditions. Hein and Rao analyzed the cost-effectiveness of various preventive maintenance treatments using performance regression models. The results concluded that preventive treatments on the pavements in good condition last 1 to 2 years longer than preventive treatments on the pavements in fair condition, while preventive treatments for pavements with lower traffic last 0.5 to 1.5 years longer than preventive treatments for pavements with high traffic. In addition, chip seal and thin overlay seem more likely to succeed in different climates.[9] Wang et al. found that the effectiveness of the treatment varies significantly with climate zone and treatment types in terms of changes of IRI values. It was found that all the four types of treatments considered in the SPS-3 sites significantly reduced IRI development at two climate conditions: warm and dry or wet and cold.[23]

Morian and Wang conducted a study to investigate the benefit–cost ratio of the treatments implemented at different years using life cycle cost.[6] Relevant results are generalized in Table 3. Results from PennDOT data indicate there is an optimum pavement age when the benefit-cost ratio associated with a treatment is maximized. Crack sealing, chip seal and microsurfacing reach their maximum effectiveness after five years of pavement construction. Crack sealing shows the highest benefit-cost ratio.

Table 3. Benefit-cost Ratio according to the Timing of the Treatment [6]

Preservation Type	Preservation Cost($ per lane mile)	Year Future Preservation Performed (year)	Extension life (year)	Benefit-Cost Ratio
Crack Sealing	$,2000	3	2	15.57
Chip Seal	$10,000	3	2.5	3.08
Microsurfacing	$20,000	3	3	1.42
Thin Overlay	$30,000	3	4	1.09
Crack Sealing	$2,000	5	4	34.18
Chip Seal	$10,000	5	5	7.55
Microsurfacing	$20,000	5	6.2	4.13
Thin Overlay	$30,000	5	7.5	2.99
Crack Sealing	$2,000	7	2	19.91
Chip Seal	$10,000	7	3	5.1
Microsurfacing	$20,000	7	4.5	3.39
Thin Overlay	$30,000	7	8.5	3.95
Crack Sealing	$2,000	10	1	11.82
Chip Seal	$10,000	10	2	3.98
Microsurfacing	$20,000	10	3	2.63
Thin Overlay	$30,000	10	7	4.06

Selection Guidelines of Preservation Used by State DOTs

Preservation treatment selection methods vary in state DOTs. For example, South Dakota DOT does not have any formal guidelines for choosing the most appropriate treatment for a certain pavement. Preventive treatments other than chip seals or sand seals have not been used except on an experimental purpose.

Pavement maintenance in South Dakota is generally a choice between chip seal and HMA overlay.[28] Typically, a chip seal is almost always placed between 3 and 5 years after placing the AC surface. The timing of the second application of chip seal is usually 6 to 8 years after the first application. A third chip seal may be applied occasionally since by that time the pavement is usually a candidate for a thin overlay.

The SDDOT developed the Enhanced Pavement Management System – Visual Distress Manual that detailed the distresses monitored and provided the definitions of various distresses for the selection of preservation treatments. It divides the crack into three severity levels and 4 extent levels for a total of 12 categories according to the severity and extents of cracking, as shown in Table 4.[29] Each category is specifically defined related to the recommended maintenance treatment.

SDDOT's experience shows that pavements that are structurally deficient are not appropriate candidates for chip seals, since wide cracks or cracks experiencing large

movements are expected to reflect through the chip seal treatment. Though chip sealing is predominantly used on low-volume to medium-volume roadways, several agencies are experimenting with chip seals on higher volume roadways.[26]

Table 4. SDDOT's Selection of Maintenance Treatment

Pavement Distress	Severity Level	Extents	Cracking Sealing	Fog Seals	Srcub Seals	Micro-surfacing	Chip Seal	Thin HMA Overlay
Transverse Cracking	Low	Low	R	F	NR	R	R	NR
		Moderate	R	F	NR	R	R	NR
		High	F	F	NR	R	R	NR
		Extreme	NR	F	NR	R	R	NR
	Medium	Low	R	F	NR	F	F	F
		Moderate	R	F	NR	F	F	F
		High	F	NR	NR	F	F	R
		Extreme	NR	NR	NR	F	F	R
	High	Low	NR	NR	NR	F	NR	R
		Moderate	NR	NR	NR	F	NR	R
		High	NR	NR	NR	NR	NR	R
		Extreme	NR	NR	NR	NR	NR	R

R=Recommended; F=Feasible Treatment; NR=Treatment is not recommended

Severity level:
Low=Crack width is less than ¼ inch;
Medium=Crack width is greater than 1/4 inch and less than 1 inch;
High= Crack width is greater than 1 inch;
Extents:
Low=Crack spacing is greater than average spacing;
Moderate=Crack spacing is less than 50 feet and greater than 25 feet average spacing;
High= Crack spacing is less than 25 feet and greater than 12 feet average spacing;
Extreme= Crack spacing is less than 12 feet average spacing.

Guidelines in Illinois DOT and Ohio DOT also select treatments based on the distress severity.[30],[31] Table 5 shows the treatment selection table used by IDOT. However, the method only provides the basic selection recommendation. Under several categories, it may recommend the same available treatments. For example, the manual usually recommends crack seals, slurry seals, or chip seals in the pavement with low-severity distress. The recommended treatment in the pavement with medium-severity or high-severity distress is thin HMA overlay.

Table 5. IDOT's Selection of Maintenance Treatment

Pavement Condition	Distress Levels	Crack Sealing	Fog Seal	Sand Seal	Slurry Seal	Micro-surfacing	Chip Seal	Cape Seal
Fatigue Cracking	L1	F	NR	NR	F	F	F	F
	L2,L3,L4	NR	NR	NR	NR	NR	NR	NR
Rutting	N1,N2	NR	NR	NR	F	R	F	F
	N3	NR	NR	NR	NR	F	NR	NR
Transverse Cracking	O1	NR	F	R	F	R	R	R
	O2,O3	R	NR	NR	NR	F	F	F
	O4,O5	F	NR	NR	NR	NR	NR	NR
Longitudinal Cracking	Q1	R	F	F	F	F	F	F
	Q2,Q3	R	NR	NR	NR	F	F	F
	Q4,Q5	NR	NR	NR	NR	NR	NR	NR
Friction	Poor	NR	NR	R	R	R	R	R
ADT	<5000	R	R	R	R	R	R	R
	5000-10000	R	F	F	F	R	R	R
	>10000	R	NR	NR	NR	F	F	F
Relative Cost		$	$	$$	$$	$$	$$	$$

F=Feasible treatment but depends upon other project constraints including other existing distresses; NR=Treatment is not recommended to correct the specified pavement condition.

Caltrans's treatment type selection[32] is very specific in the guidelines used based on the climate, traffic and geography effect, shown in Table 5. The same treatments are also specified according to the material, although these impacts on the selection of preservation treatments are not significantly different.

Some states develop their own pavement distress indicators and use them in the selection of preservation treatments. They also use a decision tree model to incorporate a set of criteria for selecting a particular treatment through the "branches." Each branch represents a specific set of conditions.[33] For example, Michigan DOT develops RQI (Ride Quality Index) and DI (Distress Index) and uses them as the marginal value to select a specific treatment, as shown in Figure 4. Figure 5 is an illustration of Minnesota DOT Network decision tree.

Table 6. Caltrans Asphalt Pavement Preservation Treatment Selection Guidelines

Treatment	Pavement Condition										Parameters													
				Rutting		Alligator					Climate				Traffic Volume									
	Raveling	Oxidization	Bleeding	<1/2"	>1/2"	0 to 10%	10 to 20%	20% to 30%	Longitudinal Cracking	Transverse Cracking	Desert	Vally	Coastal	Mountain	ADT<5000	3000<ADT<5000	ADT<3000	Night/Cold	Stop Point	Urban	Rural	high snow plow use	Cost of per lane mile($	Life Expectancy(year)
Crack Seal																								
Emulsion	N	N	N	N	N	F	P	N	F	F	G	G	G	G	G	G	G	N	G	G	G	G	2500	1-2
Modified (Rubber)	N	N	N	N		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	2500	2-3
Fog Seal	F	G	N	N	N	F	P	N	P	P	G	G	G	G	F	N	N	P	F	G	G	F	4500	1
Slurry Seal																								
Type II	F	G	N	N	N	F	N	N	N	N	G	G	G	F	G	G	G	P	G	G	G	P	13000	3-4
Type III	G	G	N	G	G	F	P	N	N	N	G	G	G	F	G	G	G	N	G	G	G	P	13000	3-4
Microsurfacing																								
Type II	G	G	N	G	N	F	N	N	N	N	G	G	G	G	G	G	G	F	G	G	G	F	16000	3-4
Type III	G	G	N	G	G	F	P	N	N	N	G	G	G	G	G	G	G	F	G	G	G	F	16000	3-4
Chip Seal																								
PME-Medium, fine	G	G	N	F	N	G	F	N	P	P	G	G	F	F	G	G	N	N	P	P	G	P	6500	1-5
PME-Medium	G	G	N	F	N	G	G	N	P	P	G	G	F	F	G	N	N	N	P	P	G	P	6500	1-5
PMA-Medium	G	G	N	F	N	G	G	N	P	P	G	G	G	G	G	N	G	N	P	P	G	P	12500	4-5
PMA-Coarse	G	G	N	F	N	G	G	N	P	P	G	G	G	G	N	N	G	N	P	P	G	G	12500	4-5
AR-Medium	G	G	N	F	N	G	G	G	F	P	G	G	G	G	G	N	G	N	P	P	G	F	20000	4-6
AR-Course	G	G	N	F	N	G	G	G	F	P	G	G	G	G	N	N	G	N	P	P	G	G	20000	4-6
Thin Asphalt Overlay																								
Conventional	G	G	P	G	G	G	G	F	P	P	G	G	G	G	G	G	G	G	G	G	G	G	20000	3-5
PBA	G	G	P	G	G	G	G	G	F	F	G	G	G	G	G	G	G	G	G	G	G	G	25000	3-6
R(Type)	G	G	P	G	G	G	G	G	G	G	G	G	G	G	G	G	G	F	G	G	G	G	30000	5-8
Dig-outs	P	P	G	N	G	N	N	G	P	P	G	G	G	G	G	G	G	F	G	G	G	G	19000	5-8

G=Good; F=Fair; P=Poor; N=Not Recommended;
PMA/PME=Polymer Modified Asphalts/Emulsions; AR=Asphalt Rubber.
RQI=Ride Quality Index; RD= Rut Depth; DI=Distress Index

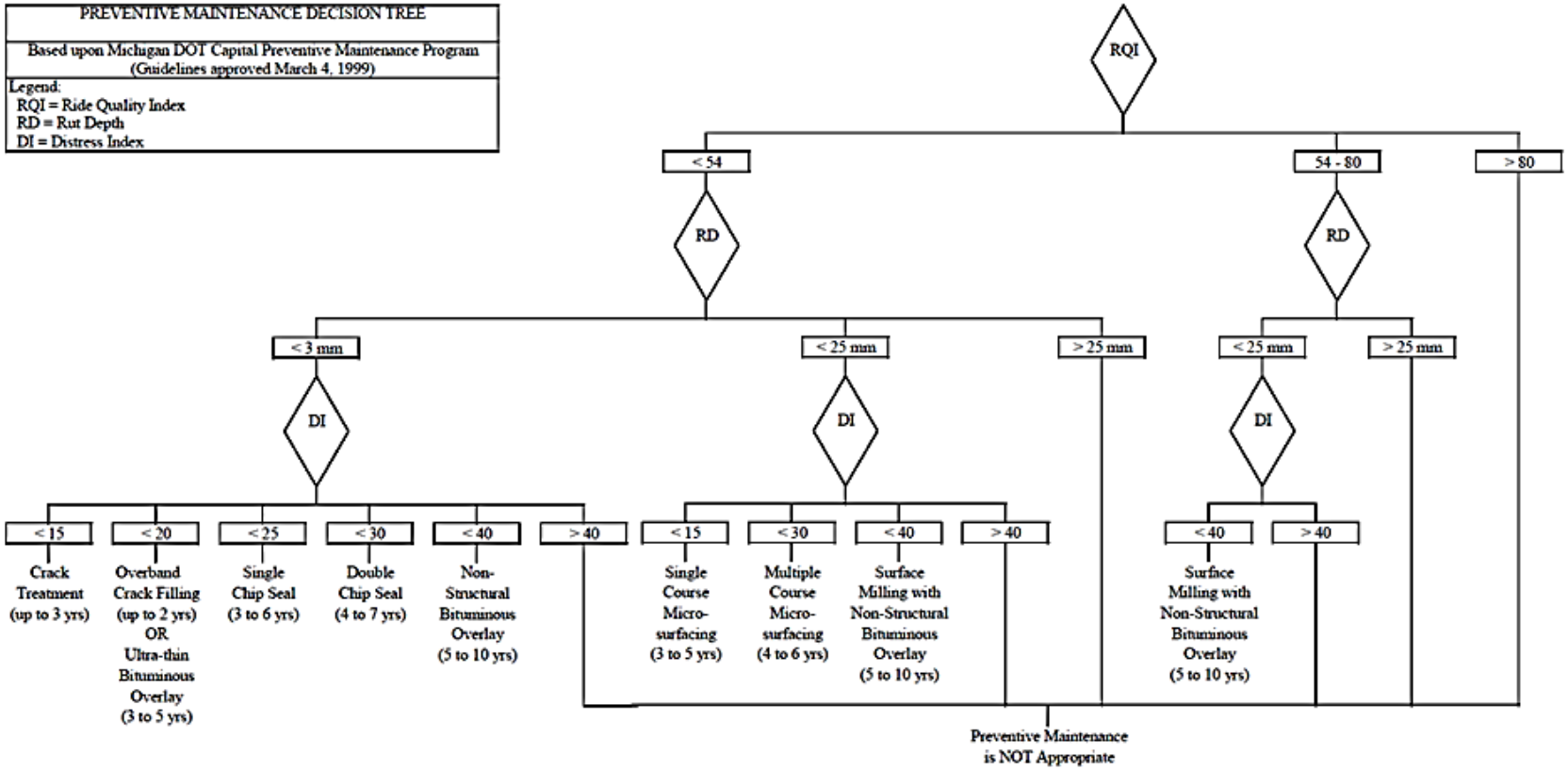


Figure 4. Preventive Maintenance Decision Tree in Michigan DOT

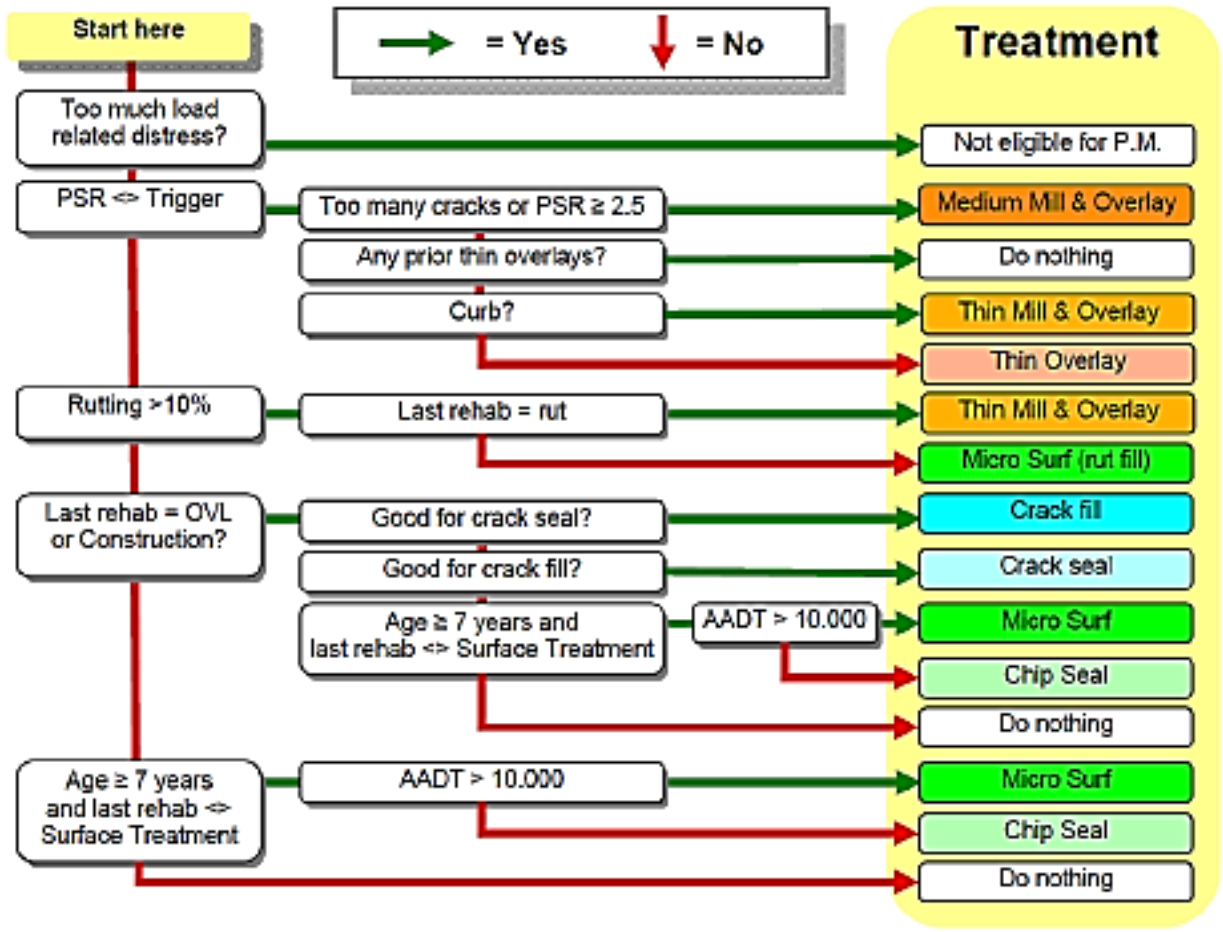


Figure 5. Minnesota DOT Network Decision Tree
* PSR 0-5 Scale

Table 7 Summaries the Treatment Recommendations Based on Distress Type and Severity Level from SHRP 2 REPORT S2-R26-RR-1 Preservation Approaches for High-Traffic-Volume Roadways.

Table 7. Summary of Treatment Recommendations Based on Distress Type and Severity Level

[REPORT S2-R26-RR-1 Preservation Approaches for High-Traffic-Volume Roadways, SHRP2, 2011]

Preservation Treatment	Window of Opportunity		Distress Types and Severity Levels (L = Low, M = Medium, H = High)										
			Surface Distress					Cracking Distress					
	PCI/ PCR	Age (yr)	Ravel/ Weather	Bleed/ Flush	Polish	Segre-gation	Water Bleed/ Pump[a]	Fatigue/ Long WP/ Slippage	Block	Trans Therm	Joint Reflect	Long/ Edge
			L/M/H	—	—	L/M/H	—	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H
Crack fill	75–90	3–6[d]						× × ×	⊙○×	○× ×	○× ×	●⊙○
Crack seal	80–95	2–5[d]						× × ×	⊙○×	●⊙○	●⊙○	○× ×
Slurry seal (Type III)	70–85	5–8	⊙●⊙	×	⊙	⊙○×	⊙	⊙○×	●⊙○	⊙○×	⊙○×	⊙○×
Microsurfacing: Single	70–85	5–8	⊙●⊙	×	⊙	●⊙○	⊙	⊙○×	●⊙○	⊙○×	⊙○×	⊙○×
Microsurfacing: Double	70–85	5–8	⊙●⊙	×	⊙	●⊙○	○	⊙○×	●⊙○	●⊙○	●⊙○	●⊙○
Chip seal: Single Conventional Polymer modified	70–85	5–8	⊙●⊙	○	●	●⊙○	⊙	⊙× ×	●⊙○	●⊙○	●⊙○	⊙⊙○
Chip seal: Double Conventional Polymer modified	70–85	5–8	○⊙⊙	×	⊙	⊙⊙○	×	⊙○×	●⊙⊙	●⊙⊙	●⊙⊙	●⊙⊙
Ultra-thin bonded wearing course	65–85	5–10	⊙●⊙	×	●	⊙⊙○	○	⊙○×	⊙⊙○	⊙⊙○	⊙⊙○	⊙⊙○
Ultra-thin HMAOL	65–85	5–10	⊙●⊙	×	●	⊙⊙○	○	⊙○×	⊙⊙○	⊙⊙×	⊙⊙×	⊙⊙×
Thin HMAOL	60–80	6–12	⊙●⊙	○	●	⊙⊙○	○	●⊙○	●●⊙	⊙●⊙	⊙●⊙	⊙⊙●
Cold milling and thin HMAOL	60–75	7–12	○⊙●	○	○	⊙●⊙	×	⊙⊙○	○⊙⊙	⊙⊙●	⊙⊙●	○⊙●
Hot in-place recycling Surf recycle/HMAOL Remixing/HMAOL	70–85	5–8	○⊙●	○	○	⊙●⊙	○	⊙⊙○	●⊙○	○⊙●	○⊙●	⊙⊙○
Repaving	60–75	7–12	×○○	○	⊙	×○⊙	×	⊙●⊙	⊙●⊙	⊙●⊙	⊙●⊙	⊙●⊙
Cold in-place recycling and HMAOL	60–75	7–12	× ×○	○	○	×○⊙	×	⊙●⊙	⊙●⊙	⊙●⊙	⊙●⊙	⊙●⊙
Profile milling	80–90	3–6	○⊙⊙	⊙	○	×○○	×	× × ×	× × ×	× × ×	× × ×	× × ×
Ultra-thin whitetopping	60–80	6–12	× ×○	○	⊙	×○⊙	×	○⊙⊙	○⊙⊙	○⊙⊙	○⊙⊙	○⊙●

Note: ● = Highly Recommended; ⊙ = Generally Recommended; ○ = Provisionally Recommended; × = Not Recommended.

It can be obtained from the above guidelines that common preservation treatments are crack seal, chip seal, slurry seal, microsurfacing, and thin overlay. Crack seal is always a favorable choice in low traffic conditions and low crack severity. Chip seal and slurry seal can be applied in pavement with low or medium traffic and when crack severity is low. Thin overlay and microsurfacing are suitable for most conditions. From the perspective of pavement performance, most guideline can be simplified into the conclusions above. However, if cost is considered, the current guidelines may not select the most cost-effectiveness treatment.

A survey conducted in Canada found a lack of information on the timing of preventative treatments and a lack of a standardized condition rating method between pavement management systems.[34] Researches recommend considering more factors in the selection of preservation treatment, including the type and extent of distress, traffic loading, climate, existing pavement type, cost of treatment, expected life, availability of qualified contractors, availability of quality materials, timing of placement, noise, and friction.[8]

Davies and Sorenson studied the SPS-3 and SPS-4 sections in LTPP of the Southern Region in the U.S.[35] This study provides a more sophisticated decision matrix, as shown in Table 8.

Table 8. Guidelines for Effective Maintenance Treatment [35]

Pavement Conditions		Parameters	Thin overlay	Slurry Seal	Crack Seal	Chip Seal(Fine)	Chip Seal(Course)	Micro Surface	Fog
Traffic	ADT/Lane	<1000	E	E	E	E	E	E	E
		100<ADT<4000	E	E	E	E-Q	E-Q	E	E-Q
		>4000	E	E	E	E-N-Q	E-N-G	E	E-Q
	Ruts	<3/8in	E	E	E	E	E	E	E
		3/8in<R<1in	E	M-N	E	M-N-Q	M-N-Q	E	T
		>1 in	E	E	E	T	T	E	T
Cracking	Fatigue	Low	E	E	E	E	E	E	M
		Moderate	E	M	M	E	E	M	T
		High	M	T	T	E	E	T	T
	Longitudinal	Low	E	E	E	E	E	E	M
		Moderate	E	M	E	E	E	M	T
		High	E	T	M	M	M	T	T
	Transverse	Low	E	E	E	E	E	E	M
		Moderate	E	M	E	E	E	M	T
		High	M	T	M	M	M	T	T
Asphalt Surface Condition	Surface Appearance	Dry	E	E	T	E	E	E	E
		Flushing	E	E	T	M-Q	E	E	T
		Bleeding	E	E	T	N-Q	E-Q	E	T
		Variable	E	E	T	M-Q	N-Q	E	M
	Raveling	Low	E	E	T	E	E-Q	E	E
		Moderate	E	E	T	E	E	E	M
		High	E	M	T	E-Q	E	E	M
	Potholes	Low	E	E	T	E	E-Q	E	T
		Moderate	E	M	M	E	E	M	T
		High	M	M	M	E	M	M	T
Existing Pavement Texture is Rough			E	E	T	M-Q	M-Q	E	T
Poor Ride			E	E	T	T	E	M	T
Rural (minimum turning movement)			E	T	T	E	E	E	E
Urban (minimum turning movement)			E	E	E	E-Q	E-Q	E	E
High Snow Plow Usage			E	E	E	E-Q	E-Q	E	E
Low Frictional Resistance			E	E	T	E	E	E	T

E=Effective; M=Marginally effective; N=Not recommended; Q=Requires a higher degree of expertise and quality control; T=Not effective.

NATIONAL SURVEY

The research team developed a multilevel State and Industry Survey tool to develop a comprehensive *Point of Contact* (POC) list, identifying agencies that have experience with using pavement preservation treatments and have incorporated them into their PMS and targeted focus group questions to develop more detailed information though phone interviews. The survey was distributed through the AASHTO RAC Listserv. The information gathered through these sources was used to develop pavement preservation treatments recommendations for use on State-maintained roads throughout New Jersey and within the PMS software.

From the responses, a POC list was developed and library including treatment descriptions, current use, limitations, specifications and testing, construction procedures and quality assurance testing, and industry manuals for NJDOT's Pavement and Drainage Management and Technology unit, Bureau of Materials, Bureau of Local Aid, Bureau of Maintenance Operations, and the Pavement Preservation Task Force.

The Survey Instrument is included in Volume 2, Appendix 3. The POC list is provided in Volume 2, Appendix 4 and the Survey Summary is in Volume 2, Appendix 5. Table 9 is a list of state DOTs responding to the survey.

Table 9. Survey Summary

ALASKA	MINNESOTA
CALIFORNIA	MISSISSIPPI
INDIANA	MONTANA
KANSAS	NORTH DAKOTA
LOUISIANA	WASHINGTON State DOT
MAINE	WISCONSIN
MICHIGAN	WYOMING

Fourteen states responded to the survey.

All States reported that their department of transportation use pavement preservation treatments in its general pavement treatments toolbox. Twelve states reported that their departments incorporate pavement preservation treatments in its pavement management system analysis. Table 10 provides a summary of the types and numbers of treatments used.

Table 10 Pavement Preservation Treatment use summary

Treatment	Number of States
Crack Sealing	12
Slurry Seal	5
Fog Seals	5
Chip Seals	13
Microsurfacing	9
Thin Overlay/Ultrathin Overlay	8
Hot In-place Recycling	2
Cold In-place Recycling	5

Maine and Montana do not consider availability of contractors when selecting the pavement preservation treatment.

DEIGHTON CUSTOMER SURVEY

Deighton has the leading market share of state DOT pavement management systems in the U.S., including NJDOT. The Deighton Associates team members identified which of their state users have incorporated Pavement Preservation Treatments into their Deighton's Total Infrastructure Management Software dTIMS PMS software. The PMS Engineer in these states was interviewed to better understand which Pavement Preservation Treatments they are using on their HMA, composite and PCC pavements, the decision trees or engineer rules they used to select the individual treatments, the reset values, the life extension used, and treatment costs used in their PMS software.

Initial Survey

An initial survey on the usage of pavement preservation treatments by state DOTs was distributed to states listed in Table 11.

Table 11. State DOTs Surveyed

State DOT's using dTIMS			
Arkansas	Louisiana	North Dakota	Rhode Island
Colorado	Maine	Ohio	South Dakota
Connecticut	Massachusetts	Oklahoma	Utah
Indiana	Mississippi	Oklahoma	Vermont
Iowa	New Hampshire	Pennsylvania	West Virginia

Database Research

Deighton Associates, Ltd conducted a review of their customer's PMS databases to determine the Pavement Preservations Treatments incorporated, Treatment Triggers, Treatment Condition Resets, and Treatment Costs. Results of this review are summarized in Table 12 for the six most common pavement preservation treatments (Crack Seal, Chip Seal, Microsurfacing, and Thin Overlay for asphalt pavements, and Joint Seal and Diamond Grinding for concrete pavements). Other pavement preservation treatments used by client states are included in Table 13.

Table 12. Client Agency Preservation Treatments

Agency	Surface Type					
	Asphalt				Concrete	
	Crack Seal	Chip Seal	Micro Surface	Thin Overlay	Joint Seal	Diamond Grind
Arkansas	X		X	X		X
Colorado	X	X	X	X	X	X
Connecticut		X	X	X		X
Indiana		X	X	X		
Iowa	X	X	X	X		X
Lousiana			X	X	X	
Maine	X	X	X	X		
Massachusetts	X	X	X	X		
Mississippi	X			X		
New Hampshire	X					
North Dakota		X				
Ohio	X	X	X	X		
Rhode Island	X	X				
South Dakota	X	X	X	X	X	
Utah		X	X			X
Vermont				X		
West Virginia	X	X		X		X

Yellow NE States, Blue other cold-regions states

Table 13. Additional Client Treatments

Agency	Other Preservation Treatments
Colorado	Asphalt Sand Seal
Indiana	Ultrathin Bonded Wearing Surface
Iowa	Seals and Thin Overlay combined as "Thin Surface Treatment"
Louisiana	Polymer Surface Treatment
Ohio	Double Microsurface, Novachip, Double Chip Seal
Utah	Seals include Low, Medium, High
West Virginia	Minor Overlay (Concrete)

Treatment Triggers

Tables 13 – 19 contain the treatment triggers used in the various pavement management systems researched by Deighton. Note that for most indexes, a scale of 1 to 100 or 0-5 is used by state agencies. Some states, such as Iowa, us the actual IRI and faulting levels in the treatment triggers.

Table 14. Crack Seal Treatment Triggers

State Agency	Road Class	PCI	RSL	Non-Structural Cracking	Longitudinal Cracking
Arkansas (AHTD)	Priority	>50		70-90	
Arkansas (AHTD)	Non-Priority	>50		60-80	
Colorado DOT	All		>=5		65-95
Iowa	All				
Maine	All				
Massachusetts	Interstate				3.6-4.1
Massachusetts	Non-Interstate				3.6-4.1
New Hampshire					
Rhode Island	Principal				60-90
Rhode Island	Interstate				70-90
South Dakota					

State Agency	Road Class	Transverse Cracking	Structural Cracking	IRI	Rutting
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT	All	65-95	>75	>65	>65
Iowa	All				
Maine	All				
Massachusetts	Interstate	3.6-4.1	>=3.7		>=3.9
Massachusetts	Non-Interstate	3.6-4.1	>=3.3		>=3.9
New Hampshire		3-4	3-4		
Rhode Island	Principal	60-90	>80	>65	
Rhode Island	Interstate	70-90		>80	
South Dakota					

Table 14 (cont.): Crack Seal Treatment Triggers

State Agency	Road Class	Roughness	Raveling	Age
Arkansas (AHTD)	Priority			
Arkansas (AHTD)	Non-Priority			
Colorado DOT	All			
Iowa	All			>2
Maine	All			>2
Massachusetts	Interstate	>=3	>=3.7	
Massachusetts	Non-Interstate	>=3	>=3.8	
New Hampshire				5-10
Rhode Island	Principal			
Rhode Island	Interstate			
South Dakota				2

Table 15. Chip Seal Treatment Triggers

State Agency	Road Class	PCI / PCR	RSL	Non-Structural Cracking	Longitudinal Cracking
Arkansas (AHTD)	Priority	>40		60-80	
Arkansas (AHTD)	Non-Priority	>40		50-60	
Colorado DOT	All		>6		>80
Connecticut	All			5-6.75	
Indiana	Non-interstate	75-95			
Iowa	All				
Iowa	All				
Maine	Rural	>4		>90	
Massachusetts	Non-Interstate				3.2-4
North Dakota					
Rhode Island	Non-interstate				50-70
South Dakota					

State Agency	Road Class	Transverse Cracking	Block Cracking	Structural Cracking	IRI
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT	All	>80		>80	>80
Connecticut	All			>5.5	
Indiana	Non-interstate				<130
Iowa	All				
Iowa	All			<63 5	<140
Maine	Rural			>93	
Massachusetts	Non-Interstate	3.2-4		>=3.7	
North Dakota					<100
Rhode Island	Non-interstate	50-70	50-70	>70	
South Dakota		>3.5	>=3.4	>3.3	

Table 15. (cont.): Chip Seal Treatment Triggers

State Agency	Road Class	Rutting	Raveling	Roughness	Patching
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT	All	>80			
Connecticut	All				
Indiana	Non-interstate	<0.25			
Iowa	All				
Iowa	All	<0.75			
Maine	Rural	>70		>90	
Massachusetts	Non-Interstate	>=4	2.9-3.8	2.9-3.4	
North Dakota					
Rhode Island	Non-interstate				
South Dakota		>=3.5		>4	>=2.3

State Agency	Road Class	Friction	AADT	Age	
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT	All				
Connecticut	All		<=5000		
Indiana	Non-interstate		<=5000	8-12	
Iowa	All	<37			
Iowa	All			>5	
Maine	Rural		<5000		
Massachusetts	Non-Interstate		<=5000		
North Dakota				>3	
Rhode Island	Non-interstate				
South Dakota					

Table 16. Microsurfacing Treatment Triggers

State Agency	Road Class	PCI / PCR	RSL	Non-Structural Cracking	Longitudinal Cracking
Arkansas (AHTD)	Priority	>40		60-80	
Arkansas (AHTD)	Non-Priority	>40		50-60	
Colorado DOT			11-20		
Connecticut	Composite			5.5-7	
Connecticut	Flexible			5-7	
Indiana		85-95			
Iowa					
Iowa					
Louisiana	Arterial			>95	
Louisiana	Collector			>95	
Louisiana	Interstate			**>98**	
Maine		>3.8		>80	
Massachusetts	Non-Interstate				>=3.
South Dakota					

State Agency	Road Class	Transverse Cracking	Structural Cracking	IRI	Roughness
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT			50-85	>65	
Connecticut	Composite		>=6.25	>=5	
Connecticut	Flexible		>=6	>=5	
Indiana				<100	
Iowa					
Iowa				<140	
Louisiana	Arterial		>95		>80
Louisiana	Collector		>95		>80
Louisiana	Interstate		**>98**		>85
Maine			>90	>70	
Massachusetts	Non-Interstate	>=3.6	>=3.7		2.7-3.4
South Dakota					

Table 16. (cont.): Microsurfacing Treatment Triggers

State Agency	Road Class	Rutting	Raveling	Patching	Friction
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT		50-85			
Connecticut	Composite	>=7			
Connecticut	Flexible	>=7			
Indiana					
Iowa					<37
Iowa		<0.75			
Louisiana	Arterial	65-90		>95	
Louisiana	Collector	65-90		>95	
Louisiana	Interstate	80-90		**>98**	
Maine		>45			
Massachusetts	Non-Interstate	>=2.8	2.8-3.8		
South Dakota		<=3			

State Agency	Road Class	AADT	Age
Arkansas (AHTD)	Priority		
Arkansas (AHTD)	Non-Priority		
Colorado DOT			
Connecticut	Composite	<=5,000	
Connecticut	Flexible		8-12
Indiana			8-12
Iowa			
Iowa			>5
Louisiana	Arterial		
Louisiana	Collector		
Louisiana	Interstate		
Maine		<10,000	
Massachusetts	Non-Interstate	<50,000	
South Dakota			<8

Table 17. Thin Overlay Treatment Triggers

State Agency	Road Class	PCI / PCR	RSL	Non-Structural Cracking	Longitudinal Cracking
Arkansas (AHTD)	Priority	>50		50-68	
Arkansas (AHTD)	Non-Priority	>50		40-58	
Colorado DOT	All		3-15		
Connecticut	All			5-6.5	
Indiana	Non-Interstate	75-95			
Iowa	All				
Iowa	All				
Louisiana	Arterial			80-95	
Louisiana	Collector			70-80	
Louisiana	Interstate			>=85	
Maine	Non-NHS	>3.5			
Maine	Non-NHS	>3.5			
Maine	Non-NHS	>3.5		50-80	
Maine	Non-NHS	>3.5			
Maine	Primary	>3.3			
Maine	Primary	>3.3			
Maine	Primary	>3.3		50-80	
Maine	Primary	>3.3			
Maine	Interstate	>3.3			
Maine	Interstate	>3.3			
Maine	Interstate	>3.3		50-80	
Maine	Interstate	>3.3			
Massachusetts	Non-Interstate				2.7-3.6
South Dakota					
Vermont	Interstate				>70
Vermont	Interstate				65-80
Vermont	Interstate				
Vermont	Non-Interstate				>70
Vermont	Non-Interstate				70-80

Table 17. (cont.): Thin Overlay Treatment Triggers

State Agency	Road Class	Transverse Cracking	Block Cracking	Structural Cracking	IRI
Arkansas (AHTD)	Priority			60-80	
Arkansas (AHTD)	Non-Priority			60-70	
Colorado DOT	All			>65	
Indiana	Non-Interstate				<130
Iowa	All				
Iowa	All				<635
Louisiana	Arterial			80-90	
Louisiana	Collector			>75	
Louisiana	Interstate			>=90	
Maine	Non-NHS				50-80
Maine	Non-NHS				
Maine	Non-NHS				
Maine	Non-NHS			60-90	
Maine	Primary				45-80
Maine	Primary				
Maine	Primary				
Maine	Primary			50-80	
Maine	Interstate				50-80
Maine	Interstate				
Maine	Interstate				
Maine	Interstate			50-80	
Massachusetts	Non-Interstate	2.7-3.6		3-3.7	
South Dakota		<=2.6	2-3.4	2-3.5	
Vermont	Interstate			65-80	
Vermont	Interstate			>70	
Vermont	Interstate				
Vermont	Non-Interstate			70-80	
Vermont	Non-Interstate			>70	

Table 17. (cont.): Thin Overlay Treatment Triggers

State Agency	Road Class	Rutting	Raveling	Roughness	Patching
Arkansas (AHTD)	Priority	50-80		72-90	
Arkansas (AHTD)	Non-Priority	52-70		58-80	
Colorado DOT	All	<75			
Connecticut	All	4.5-7			
Indiana	Non-Interstate	<0.375			
Iowa	All				
Iowa	All	<140		<0.75	
Louisiana	Arterial	<65		70-90	>=80
Louisiana	Collector	<65		65-80	>=70
Louisiana	Interstate	<80		85-90	>=90
Maine	Non-NHS				
Maine	Non-NHS	60-90			
Maine	Non-NHS				
Maine	Non-NHS				
Maine	Primary				
Maine	Primary	50-80			
Maine	Primary				
Maine	Primary				
Maine	Interstate				
Maine	Interstate	50-80			
Maine	Interstate				
Maine	Interstate				
Massachusetts	Non-Interstate	2-2.9	2-2.9	0.9-2.3	
South Dakota		>=1		<2.9	2-3.5
Vermont	Interstate				
Vermont	Interstate				
Vermont	Interstate	37.5-62.5			
Vermont	Non-Interstate				
Vermont	Non-Interstate				

Table 17. (cont.): Thin Overlay Treatment Triggers

State Agency	Road Class	Friction	AADT	Age	
Arkansas (AHTD)	Priority				
Arkansas (AHTD)	Non-Priority				
Colorado DOT	All				
Connecticut	All				
Indiana	Non-Interstate		<10,000	8-12	
Iowa	All	<37			
Iowa	All			>5	
Louisiana	Arterial				
Louisiana	Collector				
Louisiana	Interstate				
Maine	Non-NHS		<5,000		
Maine	Non-NHS		<5,000		
Maine	Non-NHS		<5,000		
Maine	Non-NHS		<5,000		
Maine	Primary				
Maine	Primary				
Maine	Primary				
Maine	Primary				
Maine	Interstate				
Maine	Interstate				
Maine	Interstate				
Maine	Interstate				
Massachusetts	Non-Interstate				
South Dakota					
Vermont	Interstate				
Vermont	Interstate				
Vermont	Interstate				
Vermont	Non-Interstate				
Vermont	Non-Interstate				

Table 18. Joint Sealing Treatment Triggers

State Agency	Road Class	PCI	RSL	Corner Break	Longitudinal Cracking
Colorado DOT	All		>6	<65	>50
Louisiana	Arterial				95-98
Louisiana	Collector				90-98
Louisiana	Interstate				95-98
South Dakota					
State Agency	**Road Class**	**Transverse Cracking**	**Structural Cracking**	**IRI**	**Rutting**
Colorado DOT	All	<75		>50	
Louisiana	Arterial	80-98			
Louisiana	Collector	75-98			
Louisiana	Interstate	80-98			
South Dakota					
State Agency	**Road Class**	**Roughness**	**Patching**	**Faulting**	**Age**
Colorado DOT	All				
Louisiana	Arterial	>=85	>=90	<=0.2	
Louisiana	Collector	>=80	>=90	<=0.2	
Louisiana	Interstate	>=85	>=90	<=0.2	
South Dakota					>=10

Table 19. Diamond Grinding Treatment Triggers

State Agency	Road Class	RSL	Corner Break	Longitudinal Cracking	Transverse Cracking
Arkansas (AHTD)					
Colorado **DOT**		**>6**	**<65**	**>50**	<75
Connecticut					
Iowa	Inters				
Iowa	Non-				
Iowa					
Iowa					
State Agency	**Road Class**	**IRI**	**Roughness**	**Friction**	**Faulting**
Arkansas (AHTD)			**58-86**		
Colorado **DOT**		**>50**			
Connecticut		**7.5-8.5**			
Iowa	Inters	**>100**			
Iowa	Non-	**>125**			
Iowa					**0.375**
Iowa				<37	

Treatment Costs

Table 20. Treatment Costs

Agency	Surface Type					
	Asphalt				Concrete	
	Crack Seal	Chip Seal	Micro Surface	Thin Overlay	Joint Seal	Diamond Grind
Arkansas	$1.25		$5.60	$12.78		$3.70
Colorado	$0.23	$6.50	$9.16	$8.57	$0.23	
Connecticut		$5.95	$6.11	$12.56		$10.45
Indiana	$0.20	$1.50	$5.00	$6.00		
Iowa	$0.43	$4.26	$4.26	$4.26		$3.55
Louisiana		$5.25	$5.25	$13.85	$1.92	
Maine	$0.21	$4.97	$4.97	$4.97		
Massachusetts	$1.71		$7.81	$19.46		
Mississippi		$2.04		$6.92		
New Hampshire	$0.43					
North Dakota		$3.91	$4.68	$10.85		
Ohio	X	X	X	X		
Rhode Island	$0.20	$9.53				
South Dakota	X	X	X	X	X	
Utah		$3.50	$6.00			
Vermont				$31.00		
West Virginia	$0.03	$1.30		$10.71		$2.74

Note:
Pavement treatment specifications, construction season constraints, contractor availability, and other factors influence costs in different geographic regions; these factors will need to be taken into account in estimating initial treatment costs until actual data can be collected from completed projects.

TREATMENT SELECTION FOR NJDOT

Based on the literature search, surveys, and discussions with the NJDOT units, the following Pavement Preservation and rehabilitation treatments were selected for further development of NJDOT specifications.

Flexible/Composite Pavement Preservation/Rehab Treatments
Chip Seal [NJDOT Ramps and Shoulders] Polymer Modified Emulsion Polymer Modified AC Asphalt Rubber
Fog Seal
Slurry Seal – Polymer modified Asphalt Rubber
Microsurfacing– Polymer modified Asphalt Rubber
*Hot In-place Recycling
*Cold In-place Recycling – Foamed Asphalt Asphalt Emulsion
*Full Depth Reclamation (Cement)

* The following is a list of states that included HIR, CIR, and FDR in their pavement treatment selections. [36]:

ALASKA	IDAHO	OREGON
ARIZONA	KANSAS	WASHINGTON STATE
CALIFORNIA	MINNESOTA	UTAH
COLORADO	MONTANA	SOUTH DAKOTA
FLORIDA	NEVADA	
GEORGIA	NEW MEXICO	

SPECIFICATION SEARCH

A comprehensive search was conducted of State DOT and Industry websites for specifications and special specifications, material requirements, and construction best practices. The FHWA specification library websites were used to locate state specifications.

Specifications Library
https://fhwapap04.fhwa.dot.gov/nhswp/stateSpecificationWebsites.jsp

National Highway Specifications Library
https://fhwapap04.fhwa.dot.gov/nhswp/searchSpecifications.jsp

A total of 91 specifications were reviewed for development of the NJDOT specifications.

State Breakdown

Eastern states – 37 Specifications

Maine	Delaware	Mississippi
Vermont	Virginia	Louisiana
New Hampshire	West Virginia	Ohio
Massachusetts	North Carolina	Kentucky
Rhode Island	South Carolina	Indiana
Connecticut	Georgia	Tennessee
New York	Florida	Illinois
Pennsylvania	Alabama	Missouri
	Maryland	

Western States 54 Specifications

Minnesota	Texas	Oregon
Wisconsin	Montana	Nevada
Iowa	Wyoming	California
North Dakota	Colorado	Arizona
South Dakota	New Mexico	Alaska
Nebraska	Idaho	Hawaii
Kansas	Utah	Arkansas
Oklahoma	Washington	

Specification Development

The specifications developed for NJDOT were based on a review of the specifications used in other states on state-maintained, high volume roads. The specification documents included the construction specification, material specification, and mix designs, where appropriate.

The complete specification documents are contained in **FHWA-NJ-2015-0XX, APPROPRIATE IMPLEMENTATION OF PAVEMENT PRESERVATION TREATMENTS, Volume 2.**

The following specifications were developed by the research team:

Pavement Preservation Treatments

Chip Seal Polymer Modified Emulsion, Asphalt Rubber, Polymer Modified AC
Fog Seal
Slurry Seal – Polymer modified, Asphalt Rubber
Microsurfacing – Polymer modified, Asphalt Rubber

Pavement Rehabilitation/Reconstruction Treatments

Hot In-place Recycling
Cold In-place Recycling – Foamed Asphalt, Asphalt Emulsion
Full Depth Reclamation (Cement)

EFFECT OF AVAILABLE SUPPLIERS AND CONTRACTORS ON IMPLEMENTATION

Pavement preservation contractors are a relatively new type of contractor in the Northeast. Since pavement preservation is a relatively new practice for the NJDOT, the appropriate workforce might not be readily available to perform the tasks put out to bid.

The earlier research identified a number of pavement preservations treatments that might be appropriate for the NJDOT's needs. Some consideration was also given to techniques that the local and county agencies might employ. The research team proposed to broadly examine the workforce available for each method of treatment. This involved an examination of the current industry practices and available material suppliers and contractors available within New Jersey and those that would be available externally from neighboring states. The research team interviewed state asphalt association experts and leaders to determine the types of markets that were prevalent throughout the Northeast.

To begin this process, the research team looked to establish a national guideline for the market share of pavement preservation techniques and for local regions if available. To the dismay of the team, both the National Asphalt Pavement Association and the National Center for Pavement Preservation could not provide an accurate portrayal of the actual market share that pavement preservation projects enjoy.

Both groups agreed that since the technologies are so new and basically being employed on a local level, the number of pavement preservation jobs is incredibly difficult to quantify. Larry Galehouse of the National Center for Pavement Preservation said, "Due to the competitive nature in today's environment this type of information is difficult to find. I have never seen a market share analysis between traditional pavement work and pavement preservation treatments."

With that, the research team turned its attention to interviewing individual contractor associations from neighboring Northeast states. Each state has their own unique experiences that might provide interesting and valuable to NJDOT before they move forward.

In "Pavement Preservation Compendium II - Principles of Pavement Preservation - Definitions, Benefits, Issues, and Barriers" by Larry Galehouse, James S. Moulthrop, and R. Gary Hicks (*https://www.fhwa.dot.gov/pavement/preservation/ppc0621.cfm*), the authors spell out some important pieces of information to keep in mind when examining Marketplace Pressures.

Marketplace Pressures

The issues and barriers for industry groups mostly involve reluctance to disturb the status quo and include the following:

- *Competition between the suppliers of maintenance and rehabilitation treatments*. With the shift from the traditional rehabilitation programs of pavement overlays applied every 10 to 20 years to pavement preservation programs using new or different treatments, resistance can be expected from the suppliers of traditional rehabilitation materials. For example, hot-mix suppliers will resist new cold-mix treatments because of the likely loss in market share.
- *Competition between various suppliers of maintenance treatments*. When markets have been established for certain types of treatments and a new treatment type is being introduced, industry often works to block the new products, whether for technical reasons or for business reasons, again to avoid loss of market share.
- *Political lobbying to prevent use of new maintenance treatments*. In some cases, industry will rely on political lobbying to prevent new technologies from entering the market. Again the reasons may be technical but more likely are related to the effect on the market if an agency adopts the new technology.
- *Establishing the benefits of new technologies or treatments*. Suppliers often introduce new technologies without adequate evidence of the benefits. The supplier must provide the agency with detailed documentation of the product's benefits and performance."

These "treatises" are apparent in states that surround New Jersey.

<u>Massachusetts</u>

Massachusetts does not endorse Hot or Cold in Place Recycling (HIR/CIR) in state specifications. There have been several Hot In Place projects around the state with mixed results, but they were all at the local level and not funded with state dollars. HIR and CIR projects are generally paid for with municipal funds and involve only two different contractors – Highway Rehab, Corp. out of New York and Gallagher Asphalt Corporation out of Illinois. All work is conducted during the day.

Most of the HMA producers believe that you can build a better project at similar cost using a traditional milling resurfacing approach. Both HIR/CIR require some type of surface treatment over their method. Most projects undertaken in Massachusetts are

one and done – not to be repeated. One of the recent HIR projects performed in Amherst, MA was eventually constructed properly, but the contractor had to replace the first attempt.

MassDOT implemented a program to reduce the traditional structural overlay on their Interstates by replacing the surface course with a one and a quarter inch overlay at around year 9/10 of the pavement's expected fifteen year life cycle. MassDOT's interstate roadways are the focus of the majority of the preservation treatments. Some municipalities are also doing more "preservation maintenance" and using the money they save to address other roads. The general consensus from Massachusetts is trying to break out of the "worst first" trap.

Pennsylvania

Pennsylvania has adopted and moved forward with pavement preservation techniques more so than Massachusetts. In 2013, PENN DOT did over 100 miles of microsurfacing in the state. This was in response to the MAP-21 funding for pavement preservation. There are/were four main contractors in the state that do the work – including one from New York named Suit-Kote Corporation. The Pennsylvania representative went on to say that "Some contractors are into Full Depth Reclamation."

When the state defines its pavement preservation techniques, they include a High Performance Thin Overlay and their heavily used HPTO specification is a combination of NY (mostly), OH, and NJ specifications that calls for a 6.3 mm mix.

In terms of the development of other forms of pavement preservation techniques, conventional contractors such as E.J. Breneman, LP and HRI, Inc have developed pavement preservation aspect sides to their business while other companies (such as New York Materials) have come to PA to do the work specifically.

At the state association, a large portion of the traditional membership doesn't like the new type of contractors. They view them as "stealing work and the already small market share."

Virginia

In the last several years, there has been a dramatic ramping up of pavement preservation projects in Virginia. This is evidenced by the number of contracts and the total dollar values.

In 2010 with ARRA, the state saw a big increase in pavement preservation projects. It was at an all-time high of $83 million. The number decreased in 2011 and 2012 to $58 and $53 million respectively, but the state saw a reinvigoration and recommitment to pavement preservation projects in 2013 when the total went up to $74 million. 2014 should be a similar or higher number when the year is complete.

Generally speaking, MAP 21 was a part of the reason that funding for pavement preservation has risen, but it is primarily due to the support and approval that VDOT gives those techniques.

For the most part, VA has three different types of pavement preservation categories.

- High Volume roads – Microsurfacing and Latex Modified Slurry Seals
- Medium Volume roads – Slurry Seals
- Local Roads – Other techniques

Other Techniques

- Novachip – Sometimes, the state uses Novachip as a pavement preservation technique.
- Hot in Place Recycling is not really used in Virginia since there have been a number of bad experiences.
- Cold In Place Recycling – There are no in state contractors that perform the work. Whenever the work is bid, out of state contractors perform the work. This is not an uncommon practice.
- Full Depth Reconstruction – Virginia has in-state contractors that perform that work.
- Slurry Seals – Most of the in-state contractors that perform this work have their own liquid side. They own and use their own Slurry Pavers and can perform slurry seals and microsurfacing work. Almost all of the work for slurry seals and microsurfacing projects are performed by in-state contractors. The industry started off slowly, but once the work became more prevalent, companies adapted to the needs of the state. Russell Standard is one of those companies.

Many of the pavement preservation contractors are involved in the Virginia Asphalt Association. There isn't a special category of membership and there doesn't seem to be any point of contention with them in the association.

The contractors will travel to other states to perform the work if it is a job of significant size and the working conditions are adequate. In terms of the contractors coming to NJ, it is believed that there are few that wouldn't consider it since NJ is a union state. There isn't any evidence to support that last statement, just the gut feeling of the individual interviewed.

New York

In New York, there is only one HIR company – Highway Rehab. They do all the work that is put out, but it is very little.

There are lots of chip seals that are placed throughout the state and done by local companies. The hot mix asphalt industry accepts these companies and doesn't look to push them out. New York Construction Materials Association estimates that on the local jobs, 5-10% of the jobs use chip seals on low volume roads. In terms of the higher volume roads, 25-40% of all the jobs that are bid on state work are pavement preservation type work. It goes even higher if you count thin overlays as pavement preservation work. Out of the 3 million tons that were placed in 2012, 1.3 million tons was a 6.3 mm mix.

The state also uses microseals, slurries and chip seals. There are 5 major players in the state that perform all the work. The companies that own their own oil/liquid supplies are in the best position to do the work. Some of these companies are prepared to do conventional work as well.

There are 5 main FDR companies in the state.

In preparation for this research, the association spoke with many of these companies and they all indicated that if New Jersey became a more pavement preservation friendly state, they would travel to New Jersey.

New York Construction Materials Association doesn't treat pavement preservation contractors differently. In New York, however, there is a separate group that is young in nature, but handles these types of contractors called the Liquid Asphalt Distributors Association of New York. The Liquid Asphalt Distributors of New York is a non-profit organization created for the purpose of extending and promoting the use of liquid bituminous materials through bituminous distributors and related specialized equipment.

Maryland

Generally speaking, pavement preservation is not a state initiative. It is estimated that 3% of the work done in the state is pavement preservation work. They do not estimate that the market share will go up that much in the next few years. The majority of the pavement preservation work is done at the local and county levels.

Geography plays vital role in Maryland's use of pavement preservation techniques. Due to the proximity of the contractors in Pennsylvania, more CIR work is performed in the northern Maryland counties and due to the slurry seal population in VA, southern Maryland does a lot of slurry and microsurfacing work.

For CIR work, it is not extensively used at all, but it is noticed. Almost all CIR work is done with a 2 inch overlay and the CIR contractor is almost always the subcontractor to the prime contractor.

For state work, they have a line item for slurry seals and microsurfacing, but it is used sparingly. For the most part, those two technologies are used after friction testing has shown that the roadway has friction issues. Safety, not structure, is the trigger for those techniques.

HIR has been used a few times and has never performed well. The trains are also too long. The association has estimated that they won't see a return of the technology for at least another 10 years due to the bad taste it left in everyone's mouth.

Tar and chips are a thing of the past mostly – even in rural areas because they create too many problems.

Conventional contractors are currently not looking to branch out into pavement preservation technique equipment because the market isn't there as of now.

In terms of membership in the state asphalt pavement association, they are not members. None of the pavement preservation folks are members and if they joined, a separate category would probably be introduced.

New Jersey

For the most part, the contractors in the state are in a "wait and see" attitude, but most recognize that the state might be moving in that direction. There are contractors that have begun to look at the pavement preservation technologies and will adapt if the market place dictates it. On the flip side, the industry will continue to promote mixed based preservation techniques such as thin overlays or the more traditional remove and replace methods.

Possible Disadvantages/Issues with coming to NJ

Upon discussions with some of the contractor associations, there are four main concerns with coming to New Jersey as of today for performing pavement preservation work.

- Workforce issues – unions/transportation
- Mobilization costs
- Night Work
- Lack of Quantity

Summary

One sentiment rang commonly among all the states except Massachusetts, “if you bid it, they will come.” With each of the states at different stages in the same pavement preservation adoption model, it is apparent that the industry is ready and available if the conditions are appropriate.

IMPLEMENTATION AND TRAINING

There is an expanding call for training in the pavement preservation area. The National Highway Institute (NHI) has refined existing courses and developed new courses to meet the needs of the state, county and municipal agencies. The pavement preservation industry has developed general and treatment-specific training courses for their suppliers and contractors and for the agency customers. Members of the research team can develop training programs for the NJDOT utilizing these materials contained in the FHWA, industry, and other training centers. The specifics of a pavement preservation training program are based on the needs and desires of the NJDOT units.

The following provides a list of some of the training courses available through the NHI, pavement preservation centers and industry training programs.

NHI Courses

- 131103 A, B, C – Pavement Preservation: Design and Construction of Preventive Maintenance Treatments
- 131104 – Pavement Preservation: Integrating Pavement Preservation Practices into Pavement Management
- 131106 – Transportation Asset Management
- 131110 – Pavement Preservation Treatment Construction – WEB-BASED

- 131114 - Pavement Preservation: Optimal Timing of Pavement Preservation Treatments
- 131115 – Pavement Preservation: Preventive Maintenance Treatment, Timing, and Selection
- 131116, A – Pavement Management: Characteristics of an Effective Program

National Center for Pavement Preservation (NCPP)

- Basic Concepts for Pavement Preservation
- Chip Seal Best Practices
- Slurry Seal and Micro-surfacing systems
- Top of the Curve: Fog Seals, Rejuvenators, Crack Sealing, and Filling

International Slurry Surfacing Association (ISSA)

- NCPP Slurry Seals & Microsurfacing Workshop
- ISSA/AI Webinar Series

Asphalt Institute

Asphalt Emulsion Webinar Series

- Introduction and chemistry
- Storage, handling and sampling testing, selecting the right grade
- Surface treatments (chip seals, slurry, micro, etc.)
- Emulsion aggregate mixtures
- Asphalt pavement recycling, miscellaneous applications

Pavement Preservation Treatments

- Introduction to Chip Seals & Best Practices
- Introduction to Slurry Seal & Microsurfacing & Best Practices
- Introduction to Crack Treatments & Best Practices
- Mix Design Methods for Slurry Seal/ Microsurfacing and for Chip Seals
- Combining Preservation Treatments - Recording
- ISSA Inspectors Manual Recording

National Concrete Pavement Technology Center

Concrete Pavement Preservation modules

- FHWA-NHI-131126A TTCC Preventative Maintenance and Pavement Preservation Concepts
- FHWA-NHI-131126B TTCC Concrete Pavement Evaluation
- FHWA-NHI-131126C TTCC Slab Stabilization and Slab Jacking
- FHWA-NHI-131126D TTCC Partial-Depth Repairs
- FHWA-NHI-131126E TTCC Full-Depth Repairs
- FHWA-NHI-131126F TTCC Retrofitted Edge Drains
- FHWA-NHI-131126G TTCC Load Transfer Restoration
- FHWA-NHI-131126H TTCC Diamond Grinding and Grooving
- FHWA-NHI-131126I TTCC Joint Sealing and Crack Resealing
- FHWA-NHI-131126J TTCC Strategy Selection

SUMMARY

The research introduced the typical types of preventive treatments and summarizes previous studies on the effectiveness of preservation on pavement performance. The cost and the life extension data of different preventive treatments were collected. It can be observed that for most of the treatments, the life extension is highly correlated to the construction cost; while the cost is very sensitive to treatment thickness. For crack seal, chip seal, and thin overlay, previous studies discovered their excellent performance in certain situations, which suggests that the performance of the treatment can be affected by environment, traffic and other factors.

The guidelines used by state DOTs to select preservation treatments were reviewed. Crack seal, chip seal, slurry seal, microsurfacing, and thin overlay are widely used in state DOTs' experience. Treatments such as sand seal, cape seal also show their potential effectiveness in the literature. It can be seen that the selection guidelines generally provide several candidate treatments for a certain scenario. It is usually difficult to select the best preservation treatment from the guidelines. More efforts should be devoted to find the cost-effectiveness of preventive treatments with respect to the specific existing pavement distress.

CONCLUSIONS AND RECOMMENDATIONS

The research helped to identify the most appropriate pavement preservation, rehabilitation and reconstruction treatment alternatives for use on New Jersey's high volume roads. The research accumulated a substantial digital library of treatment information and performance for NJDOT staff and provided demonstration projects of some treatment.

The research developed construction specifications, material specifications, and mix design methodologies for the seven pavement preservation, rehabilitation and reconstruction treatments selected for use on NJDOT state-maintained roads.

The research investigated the effects of supplier and contractor availability on the expected increase in the seven pavement preservation, rehabilitation and reconstruction treatments. The out of state contractors will have to supply the workforce for these treatments until supplier and contractors within New Jersey are convinced that the workload within NJ supports the need for expanding their training, equipment, and supplies.

REFERENCES

[1] FHWA, Performance Evaluation of Various Rehabilitation and Preservation Treatments, January 2010.

[2] FHWA ACTION: Preventive Maintenance Eligibility Memorandum, October 2004.

[3] FHWA ACTION: Pavement Preservation Definitions, September, 2005.

[4] REPORT S2-R26-RR-1 Preservation Approaches for High-Traffic-Volume Roadways, SHRP2, 2011.

[5] REPORT S2-R26-RR-2 Guidelines for the Preservation of High-Traffic-Volume Roadways, SHRP2, 2011.

[6]. Morian, D.A.,G., Wang, and D. Frith, Cost Benefit Analysis of Thin Surface Treatments in Pavement Treatment Strategies & Cycle Maintenance. Journal of Materials in Civil Engineering, doi: 10.1061/(ASCE)MT.1943-5533.0000563, 2012.

[7]. FP[2] Inc, http://www.fp2.org/.

[8]. Qiao, D., *Enhancement of Pavement Maintenance Decision Making by Evaluating the Effectiveness of Pavement Maintenance Treatments*. PhD diss., University of Tennessee, 2011.

9. Cuelho, E., R. Mokwa, and M. Akin, *Pavement Maintenance Treatments of Flexible Pavements: A Synthesis of Highway Practice*. Prepared for Montana Department of Transportation Research Section by the Western Transportation Institute, Report No. FHWA/MT-06-009/8117-26, 2006.

[10]. Morian, D.A., *Cost Benefit Analysis of Including Microsurfacing in Pavement Treatment Strategies & Cycle Maintenance.* FHWA-PA-2011-001-080503, 2011.

[11]. Raza, H., *An Overview of Surface Rehabilitation Techniques for Asphalt Pavements*. FHWA-PD-92-008, Federal Highway Administration, Washington, D.C., 1992.

[12]. Smith, K. L. and A. R. Romine, *LTPP Pavement Maintenance Materials: SHRP Crack Treatment Experiment*. Report No. FHWA-RD-99-143, Federal Highway Administration, Washington, D.C., 1999. 163 pp.

[13]. *Crack Sealing Benefits and Techniques*. Road Management & Engineering Journal Archives, August, 1999.

[14]. Chen, D.H., D.F. Lin, and H.L. Luo, *Effectiveness of Preventive Maintenance Treatments Using Fourteen SPS-3 Sites in Texas*. Journal of Performance of

Constructed Facilities, Volume 17, No. 3, American Society of Civil Engineering, Reston, VA (2003) pp. 136-143.

[15] . Yildirim, Y, Korkmaz, A, and Prozzi, J: Performance Comparison of Hot Rubber Crack Sealants to Emulsified
Asphalt Crack Sealants. Center for Transportation Research, The University of Texas at Austin, May 2006

[16]. Eltahan, A.A., J.F. Daleiden, and A.L. *Simpson, Effectiveness of Maintenance Treatments of Flexible Pavements*. In Transportation Research Record: Journal of the Transportation Research Board, No. 1680, Transportation Research Board of the National Academies, Washington, D.C., 1999, pp.18-25.

[17]. Wang, Y. and Wang, G., *Impact of Climate Conditions on the Effectiveness of Asphalt Pavement Preservation Techniques*. Journal of the Transportation Research Board, 2012 (in press).

[18]. Morian, D.A., J.A. Epps, and S.D. Gibson, *Pavement Treatment Effectiveness, 1995 SPS- 3 and SPS-4 Site Evaluations, National Report*. FHWA-RD-96-208. Federal Highway Administration. Washington, DC., 1997.

[19]. Carvalho,R., M. Ayres, H. Shirazi, O. Selezneva, and M. Darter, *Impact of Design Features on Pavement Response and Performance in Rehabilitated Flexible and Rigid Pavements*. FHWA-HRT-10-066, 2011.

[20]. Shirazi, H., R.L. Carvalho, M. Ayres, Jr., and O. Selezneva, *Statistical Analysis of LTPP SPS-3 Experiment on Preventive Maintenance of Flexible Pavements*. In First International Conference on Pavement Preservation, Newport Beach, CA, 2010.

[21]. Lukanen, E.O., *Preservation Effects on Performance of Bituminous over Aggregate Base Pavements in Minnesota*. Tansportation Research Record, 2007.

[22]. Peshkin, D., K.L. Smith, A. Wolters, J. Krstulovich, J. Moulthrop, and C. Alvarado, *Guidelines for the Preservation of High-Traffic-Volume Roadways*. SHRP 2 Report S2-R26-RR-2, 2011.

[23]. Michigan Department of Transportation, Capital Preventive Maintenance Manual, 2010.

24 Douglas D. Gransberg, , and Musharraf Zaman, Analysis of Emulsion and Hot Asphalt Cement Chip Seal Performance, JOURNAL OF TRANSPORTATION ENGINEERING © ASCE, MARCH 2005

[25]. Hall, K.T., C.E. Correa, A.L. Simpson, *LTPP Data Analysis: Effectiveness of Maintenance and Rehabilitation Options, National Cooperative Highway Research Program.* NCHRP Web Document 47 (Project 20-50[3/4]): Contractor's Final Report. June 2002.

[26]. Attoh-Okine, N., H. Park, *Thin Overlay Maintenance Treatment Application in Delaware Communities*. Delaware Center for Transportation, 2007.

[27]. Peshkin D.G. and T.E. Hoerner, *Pavement Preservation: Practices, Research Plans, and Initiatives*. NCHRP Project No. 20-07, Task 184, 2005.

[28]. Wade, M., R. DeSombre, and D. Peshkin, *High Volume/High Speed Asphalt Roadway Preventive Maintenance Surface Treatments*. Report No. SD99-09, South Dakota Department of Transportation, Office of Research, Pierre, SD (2001) 151 pp.

[29]. South Dakota Department of Transportation, *Pavement Preservation Guidelines*, 2010.

[30]. Illinois Department of Transportation (IDOT), *Chapter 52: Pavement Preservation. Design and Environment Manual.* Illinois DOT, Springfield, Ill, 2009.

[31]. Ohio Department of Transportation (ODOT), *ODOT Pavement Preventive Maintenance Guidelines.* ODOT, Columbus, Ohio, 2001.

[32]. Caltrans. *Maintenance Technical Advisory Guide (MTAG) – Asphalt Pavements, Sacramento*. http://www.dot.ca.gov/hq/maint, 2003.

[33]. Hicks, R.G., S.B., Seeds, and D.G., Peshkin, *Selecting a Preventive Maintainence Treatment for Flexible Pavements*. Prepared for Foundation for Pavement Preservation, 2000.

[34]. Hein, D., and J. Croteau, *The Impact of Preventive Maintenance Programs on the Condition of Roadway Networks*. Paper prepared for presentation at the Coordinating Pavement and Maintenance Management with Transportation Asset Management Session of the 2004 Annual Conference of the Transportation Association of Canada, 2004.

[35]. Davies, R.M., and J. Sorenson. *Pavement Preservation: Preserving the Investment in our Highways*. Draft Public Roads Article, November 10, 1999.

[36] . Kuennen, T., Hot, Cold In-Place Recycling Gets Boost at Western States Conference, Pavement Preservation Journal, Spring 2015