Alaska Department of Transportation & Public Facilities
Alaska University Transportation Center

Pavement Preservation Practices in Cold Regions

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13. ABSTRACT (Maximum 200 words)
The Alaska Department of Transportation and Public Facilities (AKDOT&PF) has recognized the value of pavement preservation and is in process of incorporating the concept in its road upkeep strategy. A research project was initiated to aid in the development of a pavement preservation program for Alaska. Part of the effort was to collect information on pavement preservation treatments used in cold regions. More specifically, the object was to identify the performance of pavement preservation techniques used in other similar climatic conditions (when compared to Alaska). The purpose of this report is to describe the state-of-art and best practices of pavement preservation in cold regions. The information was collected by a comprehensive literature review and by conducting a survey on pavement preservation issues. All surveyed pavement preservation treatments (Crack Sealing, Patching, Fog Seals, Chip Seals, Slurry Seals, AST/BST, Microsurfacing, Thin Overlays, Bonded Wearing Courses, Interlayers and In-place Recycling) have been used in cold regions for over 30 years. Crack sealing and patching are the most extensively used pavement preservation techniques. Recommendations for research and implementation are included.

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Disclaimer

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1. Introduction

1.1 Background

Pavement preservation became a national topic in the early 1990s, when highway agencies examined effective maintenance practices (Galehouse et al., 2011). The preservation concept is a departure from traditional approaches, which wait until deficiencies are evident or until reconstruction or major rehabilitation are the only means to correct the problem. Figure 1-1 shows graphically how pavement preservation can extend the pavement service life while maintaining a high level of service. According to FHWA (2005) a pavement preservation program consists of three components: preventive maintenance, minor rehabilitation (nonstructural), and some routine maintenance activities. The primary aim is to optimize often limited road rehabilitation and maintenance funding. The concept is currently used widely in the United States including the Northern Tier States (e.g. Baladi et al. 2002, Lee and Shields 2010, Ong et al. 2010, Peshkin et al. 2011). Other reasons for pavement preservation exits; e.g. Canada promotes pavement preservation for safety (Erwin and Tighe 2008), energy consumption and reduction of greenhouse gases (Chan et al. 2010). Others include pavement preservation in their asset management systems, e.g. Saskatchewan Highways and Transportation (Safronetz et al. 2005) and European countries (ERA-NET ROAD 2011). Yet, there are areas in the world where pavement preservation has not yet been implemented, but called for by pavement researchers, e. g. in China. Most of the treatments are corrective maintenance and repair techniques due to insufficient attention and application of pavement preservation (Chen 2007). Although it is pointed out that maintenance is proactive treatment, the maintenance and management departments should adjust their traditional maintenance concept to reflect this new approach (Chen 2007, Dong and Sun 2004).

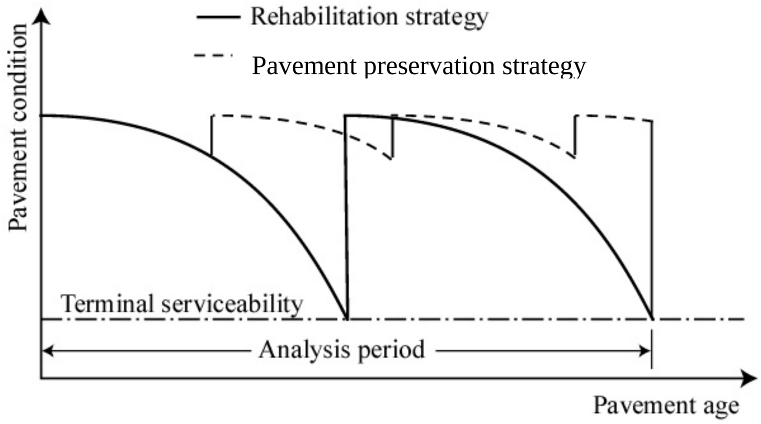

Figure 1-1. Effect of pavement preservation on pavement condition (adopted from Doré and Zubeck 2009)

Also, the Alaska Department of Transportation and Public Facilities (AKDOT&PF) has recognized the value of pavement preservation and is in the process of incorporating the concept in its road upkeep strategy. A research project "Develop Guidelines for Pavement Preservation Treatments and for Building a Pavement Preservation Program Platform for Alaska" was initiated to aid in the development of a pavement preservation program for Alaska. The project was funded by the Alaska University Transportation Center (AUTC; Project Number 410019) the AKDOT&PF and California Department of Transportation (Caltrans) and was conducted by the California Pavement Preservation Center (CP2C), the University of Fairbanks (UAF) and the University of Alaska Anchorage (UAA).

Part of the effort was to collect information on pavement preservation treatments used in cold regions. More specifically, the object was to identify the performance of pavement preservation techniques used in other similar climatic conditions (when compared to Alaska). The climatic conditions challenging pavements in cold regions include short construction season, frost action, degrading permafrost, thermal stresses, frozen water related problems (snow, ice, freeze-thaw cycling) and other indirect challenges such as use of studded tires for winter traction. Other challenges common in cold regions, include factors such as long hauling distances, lack of equipment, materials and labor.

1.2 Purpose of Report

The purpose of this report is to describe the state-of-art and best practices of pavement preservation in cold regions. It covers the treatments used in cold regions as well as their expected life, costs, and other issues. The information was collected by a comprehensive literature review and by conducting a survey on pavement preservation issues.

1.3 Organization of report

The report is organized in a following way: Chapter 2 summarizes the information obtained from the survey. The detailed survey questions, results and responders are given in appendices. Chapter 3 integrates the findings from the survey with the literature and Chapter 4 includes conclusions and recommendations resulting from the study.

2. 2011 Survey on Pavement preservation in cold regions

A survey on pavement preservation issues was created and sent to pavement experts across the cold regions, such as the U.S. states impacted by frost, other agencies in Canada, the Nordic Countries, China, Japan and Russia.

The survey questions are given in Appendix 6.1. A total of 43 pavement experts given in Appendix 6.2 responded and completed the survey. Responses were obtained from the Northern Tier States in U.S., Canada, the Nordic Countries, China and Japan. The detailed survey results are given in Appendix 6.3 and summarized in the following sections. The pavement preservation issues are grouped into the following areas (all pertaining only to cold regions):

- Extent of treatments used
- How often are treatments repeated
- Average service life for each treatment type
- Dedicated budgets for preservation
- Performance measures used
- Construction cost of treatments
- Overall summary from the survey

2.1 Extent of Treatments Used

The survey investigated the use of the following pavement preservation treatments:

- Crack Sealing
- Patching
- Fog Seals
- Chip Seals
- Slurry Seals
- Asphalt Surface Treatment/Bituminous Surface Treatment (AST/BST)
- Microsurfacing
- Thin Overlays
- Bonded Wearing Courses
- Interlayers
- In-place Recycling
- Other treatments

The following descriptions of the treatments were provided with the survey to the responders:

<u>Crack Sealing</u> – Placement of asphalt emulsions/cement at elevated temperatures into road openings, cracks, ranging from 5mm to 25mm. Sometimes fillers need to be added before applying the actual asphalt emulsion on larger openings.

<u>Patching</u> – First, a highly distressed area of asphalt or pavement is removed in a localized area, the edges and the bottom layer of the hole are prepared according to what the nature of the distress, the bottom is compacted, and then the hole is refilled with new material and compacted as well. Often this is in preparation for subsequent surface treatments.

<u>Fog Seals</u> – This is a light spray application of asphalt emulsions and water. It is used primarily to seal and waterproof existing asphalt surfaces and also to hold stone or tire chips in place.

<u>Chip Seals</u> – A chip seal is the application of a bituminous layer followed by a layer of single sized aggregate that is imbedded into the binder. Multiple layers can be applied depending on the need.

<u>Slurry Seals</u> – Mixture of asphalt emulsions, graded aggregate, mineral filler, water and additives. The slurry is mixed and placed on a continuous flow basis through a paving machine.

Surface treatment (AST/BST) - Consists of a thin layer of asphalt binder, typically high float emulsion, covered with well-graded aggregate. (Unlike the uniform particle size in a chip seal).

Microsurfacing – This treatment can be used for similar situations as slurry seals, but better graded aggregates and polymer additives are always used, curing is provided chemically instead of through the evaporation of water therefore much shorter curing times versus slurry sealing.

Thin HMA Overlays – This is typically a layer of hot mix asphalt of 37mm or less. It is not meant to be structural but preventative with some correction of current conditions such as light rutting or minor crack distress. Overlays can be of dense graded, gap graded, or open graded aggregate.

Bonded Wearing Courses – First a thick polymer modified asphalt emulsion is applied. This is followed within 5 s by a gap graded or open graded hot mix asphalt thin asphalt layer applied using a specialized paving machine. An open surface texture does exist after treatment is complete.

Interlayers – These are layers that are placed in conjunction with an overlay or surface treatment. Interlayers can be, but are not limited to paving textile, paving mat, paving grids, paving composite grids, asphalt rubber chip seal, polymer modified asphalt rubber chip seal, polymer modified rejuvenating emulsion, and microsurfacing.

In-place Recycling – This technique is usually performed either cold or hot. Both start by milling to a partial depth ranging from 50mm to 100mm, size the reclaimed material, mix with additives and/or virgin material, and repave. With the hot technique, heat is applied to the existing asphalt surface as it is being milled.

According to the survey results (see Question 4 in Appendix 6.3 and Figure 2-1), all of the aforementioned treatments are used to some extent in cold regions, some extensively and some in special cases. On the other hand, for each treatment (except for patching), there are regions in the world that never utilize them. Crack sealing and patching are the most extensively used pavement preservation techniques. Chip seals, thin overlays and in-place recycling are also used extensively, although not by so many users as crack sealing and patching. Fog seals, chip seals, micro surfacing, thin hot mix overlays, interlayers and in-place recycling are used in special cases in many cold regions. Note that the use of AST/BST is limited to permafrost areas (Doré and Zubeck 2009).

The survey also asked how long have the pavement preservation treatments been in use (see Question 8 in Appendix 6.3). The data show that all the treatments have been used in some region for almost as long as paved roads have been around, and some for at least for 30 years. Some newer treatments include microsurfacing, bonded wearing courses, interlayers, in-place recycling and some other techniques. But, even these "newer" techniques have been used somewhere in cold regions for more than 30 years. Based on these results, all of the aforementioned pavement preservation treatments have potential for use in Alaska.

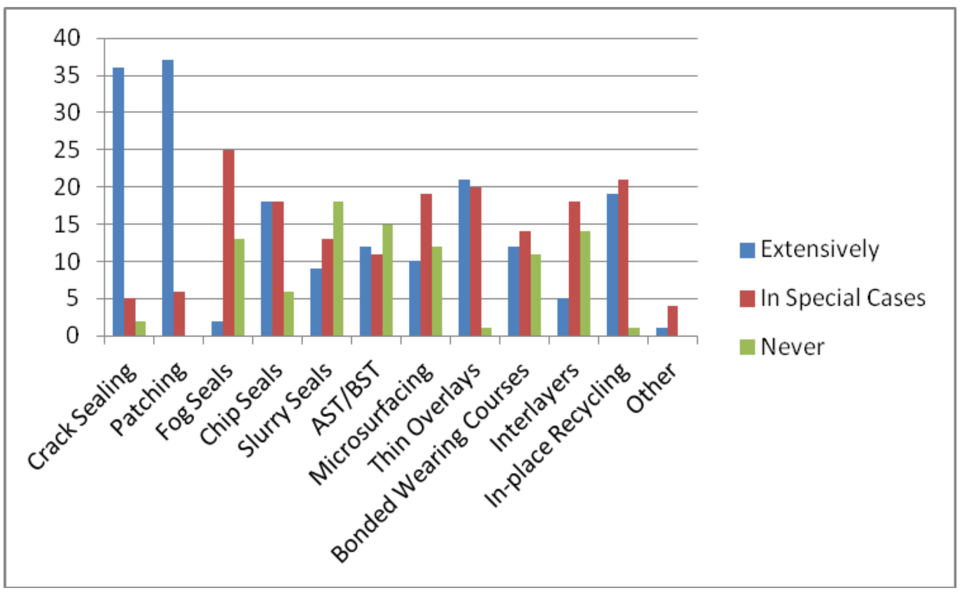

Figure 2-1. Extent of treatments used (number of responses)

The survey also asked about which pavement preservation treatments are used under different traffic volumes and in other specific conditions typical to cold regions (see Question 10 in Appendix 6.3 and Figures 2-2 to 2-4). Figure 2-2 presents the treatments used under different traffic volumes. Crack seals, patching, thin overlays, and in-place recycling are used in many areas at all traffic levels. The use of fog seals, chip seals, slurry seals and AST/BST (with the exception of ADT 500-2500) decreases with the increasing traffic volume. The use of microsurfacing, bonded wearing courses and interlayers increase with the increasing traffic volume. The gray shaded cells in Table 2-1 show the most popular traffic levels for each technique, which could also be considered as the recommended traffic levels for Alaska.

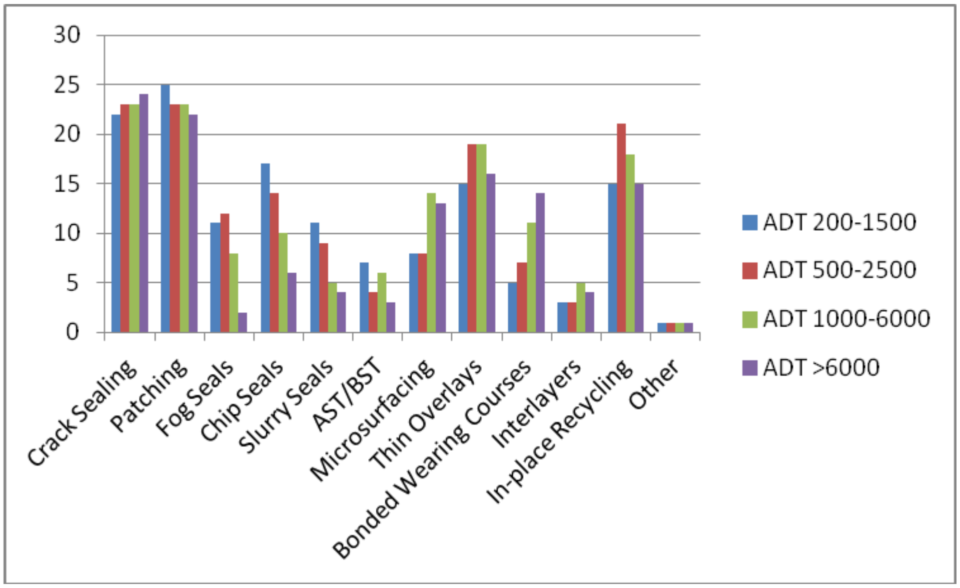

Figure 2-2. Extent of treatments used under different traffic volumes (ADT = annual daily traffic, number of responses))

Table 2-1. Use of pavement preservation techniques at various traffic volumes (number of responses)

	ADT 200-1500	ADT 500-2500	ADT 1000-6000	ADT >6000
Crack Sealing	22	23	23	24
Patching	25	23	23	22
Fog Sealing	11	12	8	2
Chip Sealing	17	14	10	6
Slurry Seals	11	9	5	4
AST/BST	7	4	6	3
Microsurfacing	8	8	14	13
Thin Overlays	15	19	19	16
Bonded Wear Courses	5	7	11	14
Interlayers	3	3	5	4
In-place Recycling	15	21	18	15
Treatment is well accepted at gray shaded traffic volumes				

Studded tires are used in many cold regions to provide traction in winter driving conditions (Zubeck et al. 2004). The studs abrade the pavement surface at various degrees depending on the stud size, which may prevent the use of certain pavement preservation treatments in areas where studded tires are used extensively. Figure 2-3 shows the extent of treatments used under heavy studded tire usage. Crack sealing, patching and thin overlays are the most commonly used treatments in these conditions followed by microsurfacing, bonded wearing courses and in-place recycling. The other surface treatments and seals as well as interlayers are seldom used.

Figure 2-4 shows the extent of treatments used in moist climates and for late season application (approaching fall and winter). All treatments are used in moist climate, fog seals being the less popular. Crack sealing, patching and thin overlays are used extensively in moist climates. Crack sealing and patching are the most used treatments for late season application, whereas all the surface treatments as well as bonded wearing courses and interlayers are seldom used.

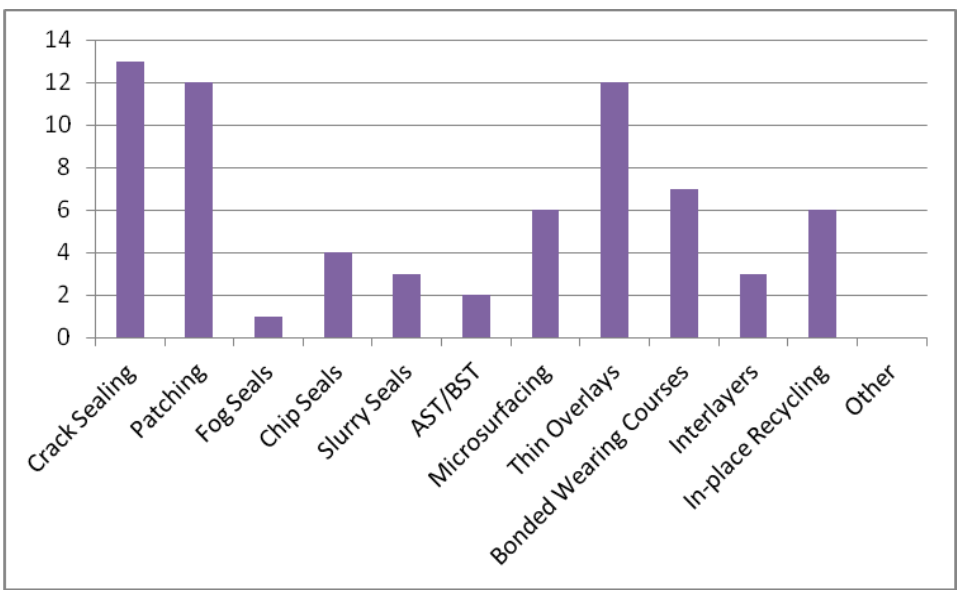

Figure 2-3. Extent of treatments used under heavy studded tire usage (number of responses)

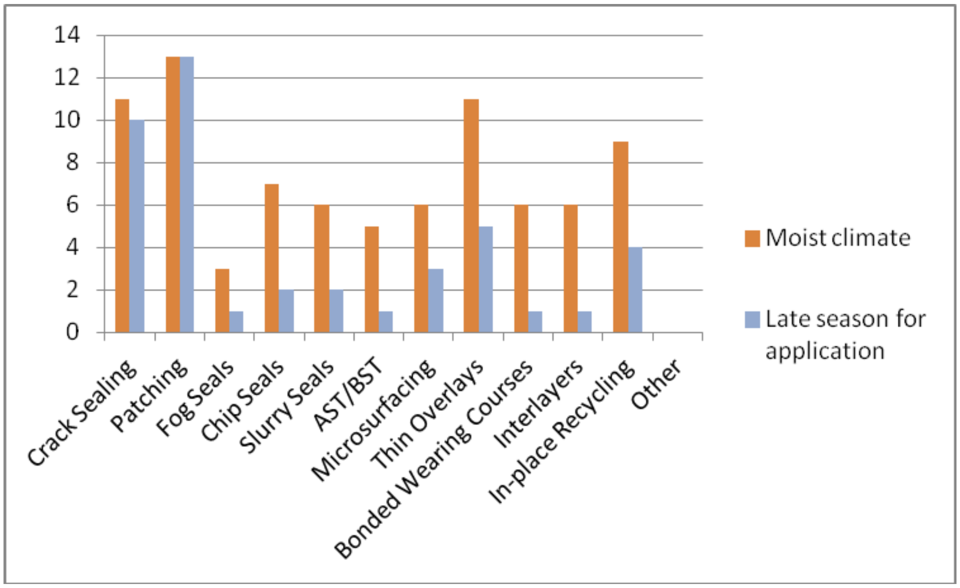

Figure 2-4. Extent of treatments used in moist climate and for late season application (number of responses)

2.2 How often are treatments repeated?

The research team wanted to chart how often each treatment is applied in cold regions (see Question 5 in Appendix 6.3 and Figure 2-5). Several responses reported applying most of the treatments only once. Crack sealing and patching are reported to be applied also at frequencies from less than 1 to 4 years.

The average frequency between the treatments cannot be calculated because "only one application" gives a spacing of infinity. However, the next question asked the average service life of the treatment used. The timing between the treatments and the service life do not necessarily match. Current pavement management system or policy and available funding affect the spacing between the treatments in addition to the actual pavement surface condition.

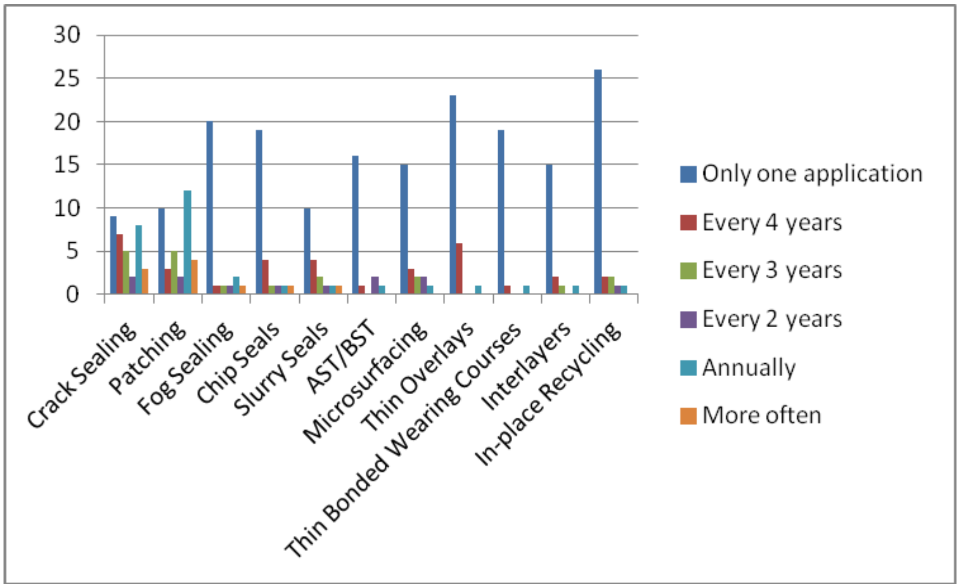

Figure 2-5. Time between treatments (number of responses)

2.3 Average service life for each treatment

The data for the average service life of each treatment is given in Question 6 in Appendix 6.3 and in Figure 2-6. Figure 2-6 presents the weighted averages for service life calculated using the median values for each life bracket in the form (e.g. for 1 - 2 years, a value of 1.5 was used in the calculations). The

weighted average = $\sum$ (number of responses * service life)/number of total responses).

The average service life of the treatments varies from about 3 years to 7 years. Crack sealing, patching and fog seals have the reported lowest service lives of about 3 years, whereas AST/BST, thin overlays, bonded wearing courses, and in-place recycling last in average 6 years or more. In-place recycling has the longest average service life of 7.8 years.

The great variability of service lives warrant further research about affecting factors and predicted service lives for Alaskan conditions.

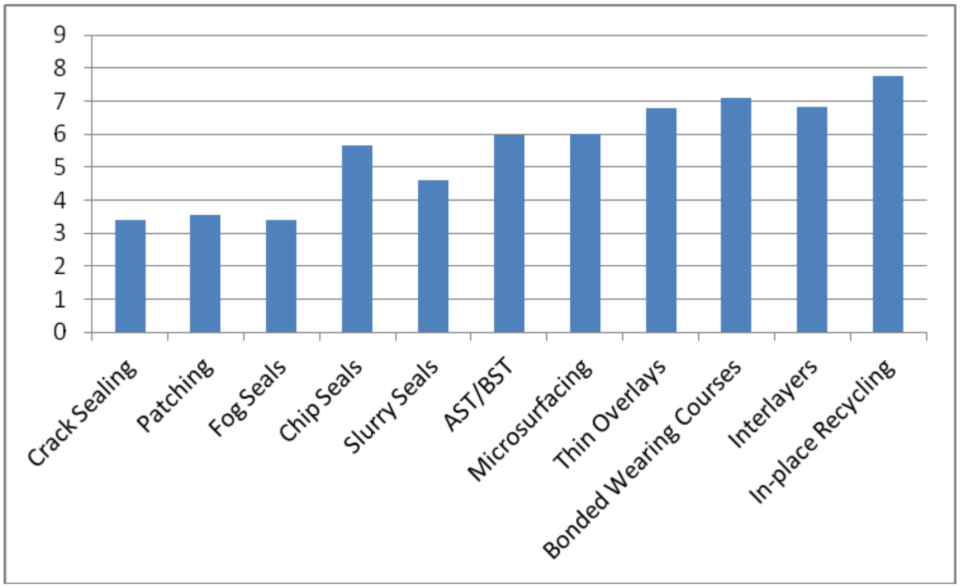

Figure 2-6. Weighted average treatment service life (years)

2.4 Dedicated budgets for preservation

Ideally, road agencies would budget separate funds for the pavement preservation. Question 7 (see Appendix 6.3) asked if the agency has a separate dedicated budget for pavement preservation. The responses (Table 2-2) show that many agencies indeed have dedicated budgets for pavement preservation. However, most agencies clearly indicated the need for additional funds.

Table 2-2. Survey responses for yes/no for dedicated budget for pavement preservation (number of responses)

	Yes	No	Not sure	% Yes
All responders	24	14	3	59
USA	5	5	0	56
Canada	9	3	0	75
Nordic Countries	5	5	1	45
Hokkaido, Japan	1	0	0	100
China	4	2	2	50

2.5 Performance measures used

Different performance measures are used to determine trigger values for the due time of pavement preservation treatments. Question 9 (see Appendix 6.3) surveyed which performance measures are used by the road agencies. The results are shown in Table 2-3. All agencies except Hokkaido, Japan use several performance measures (133 total responses by 38 responders). All measures are used extensively, IRI, rutting, cracking and expert opinion. The "other" measures included distress index, falling weight deflectometer (FWD), MicroPaver and pavement strength.

Table 2-3. Region-specific survey responses for performance measures for pavement performance (number of responses)

	IRI	Rutting	Cracking	Expert Opinion	Other (methods)
USA	8	7	7	6	1 (distress index)
Canada	10	10	11	9	3 (FWD, MicroPaver, pavement strength)
Nordic Countries	10	11	6	9	-
Hokkaido, Japan	-	1	-	-	-
China	6	6	7	5	-
Total	34	35	31	29	4 $\sum$ 133
Total responders	38				

2.6 Cost of treatments

Question 11 (see Appendix 6.3) asked "what was the average cost for each treatment in 2010 US dollars (USD)". The responses given are listed in Table 2-4 (not all responders answered the question). The costs vary from a region to another as expected. The data provides an idea about the magnitude of the cost for each treatment.

Table 2-4. Cost of pavement preservation treatments (USD)

	Crack Sealing	Patching	Fog Seals	Chip Seals	Slurry Seals	AST/BST	Microsurfacing	Thin Overlays	Bonded Wearing Courses	Interlayers	In-place Recycling
USA											
Maine	7,500/ mile		17,000/ mile				91,800/ mile	150,000/ mile			500,000/ mile
Michigan	4,500/ mile		0.50/yd^2	1.51/yd^2 (single chip seal)			3.50/yd^2 (two course)	60/ton	5.5/yd^2		
Minnesota	2,500/ mile			26,000/ mile			37,000/ mile	60,000/ mile	65,000/ mile		400,000/ mile
New Hampshire	0.90/ lb			2.15/yd^2			3.00/yd^2	2.70/yd^2	6.0/yd^2	10.0/yd^2	6.0/yd^2
New York	5,000/ lane mile		10,000/ lane mile	20,000/ lane mile	15,000/ lane mile		40,000/ lane mile	50,000/ lane mile	50,000/ lane mile		120,000/ lane mile
Wisconsin (Dane	5,000/ lane	8,000/ lane	varies	13,000/ lane mile	varies		28,000/ lane mile	40,000/ lane mile			

County)	mile	mile									
Canada											
Entire Country	2-4 /m	30-40 /m^2	11 /m^2	10 /m^2	11 /m2	16 /m^2	7 /m^2	20 /m^2	45 /m^2		50 /m^2
British Colombia	10 /m	20/m^2		10/m^2	120,000/ lane km	100,000 / lane km	10/m	20/m^2		10/m^2	$120,000/ lane km
Northern Canada		300/km				50,000/ km	75,000/k m	225,000/ km		250,000/ km	
Northern Countries											
Denmark	3.40/ m	37.00/m	1.80/m^2	5.80/m^2		5.60/m^2			24.80/m^2	3.40/m	37.00/m
Sweden	37/m^2	22/m^2	2.3/m^2	2.4/m^2	2.4/m^2	2.0/m^2		9.0/m^2	9.8/m^2 (incl. surface planing)	13/m^2	6.8/m^2
Finland											3.0/m^2
China											
Northeast	2/m^2	2/m^2	1/m^2	2/m^2	1.5/m^2	1/m^2	4/m^2	7/m^2		8/m^2	

2.7 Overall summary from the survey

The survey results provided the following findings:

- All surveyed pavement preservation treatments (Crack Sealing, Patching, Fog Seals, Chip Seals, Slurry Seals, AST/BST, Microsurfacing, Thin Overlays, Bonded Wearing Courses, Interlayers and In-place recycling) have been used in cold regions for over 30 years.
- Crack sealing and patching are the most extensively used pavement preservation techniques.
- Chip seals, thin overlays and in-place recycling are also used extensively, although not by so many users as crack sealing and patching.
- Fog seals, chip seals, micro surfacing, thin overlays, interlayers and in-place recycling are used in special cases.
- Traffic volume does not affect the use of crack seals, patching, thin overlays, or in-place recycling.
- The use of fog seals, chip seals and slurry seals decreases with the increasing traffic volume.
- The use of microsurfacing, bonded wearing courses and interlayers increase with the increasing traffic volume.
- Table 2-1 suggests recommended traffic levels for pavement preservation treatments in Alaska.
- Crack sealing, patching and thin overlays are the most commonly used treatments in heavy studded tire usage areas followed by microsurfacing, bonded wearing courses and in-place recycling. The surface treatments and seals as well as interlayers are seldom used.
- All treatments are used in moist climate, fog seals being the less popular. Crack sealing, patching and thin overlays are used extensively in moist climates.
- Crack sealing and patching are the most used treatments for late season application, whereas all the surface treatments as well as bonded wearing courses and interlayers are seldom used.
- All of the aforementioned treatments (see the first bullet) have potential for use in Alaska.
- Most of the treatments are applied only once. Crack sealing and patching are applied also at spacing from more often than annually to every 4 years.
- The average service life of the treatments varies from about 3 years to 7 years. Crack sealing, patching and fog seals have the lowest service lives of about 3 years, whereas AST/BST, thin overlays, bonded wearing courses, and in-place recycling last in average 6 years or more. In-place recycling has the longest average service life of 7.8 years. The great variability of service

lives warrant further research about affecting factors and predicted service lives for Alaskan conditions.

- Many regions have dedicated budgets for pavement preservation. Comments typically state the need for more funds.
- Most regions use several performance measures to determine trigger values for the due time of pavement preservation treatments. IRI, rutting, cracking and expert opinion are used extensively.
- The costs of treatments vary from a region to another. The data in Table 2-4 provides an idea about the magnitude of the cost for each treatment.

3. Preservation Practices in Cold regions

This chapter is based on a literature review on pavement preservation practices in cold regions. The term “pavement preservation” is not necessarily used in the current literature. Some regions use pavement preservation treatments as a part of preventive maintenance or as a part of their asset management program. The literature covered here includes publications about pavement preservation, preventative maintenance and asset management pertaining pavement preservation treatments.

The following topics are collected from the literature:

- Treatments used
- Expected life of treatments
- Problems encountered with various pavement preservation treatments
- Other issues.

3.1 Treatments used

As evident also from the survey results (Chapter 2), the pavement preservation treatments are widely used around the world's cold regions. Table 3-1 lists the treatments and the publications that cover information on the treatments. More details (if valuable for this report) are given in the following sections.

Table 3-1. Treatments used in cold regions

Treatment	Pertaining literature
Crack Sealing	Canada: Wei and Tighe 2004, Chan et al. 2010, Indiana: Lee and Shields 2010, Illinois: Wolters et al. 2009, China: Xue et al. 2003, Yuan 2004
Patching	Canada: Wei and Tighe 2004
Fog Seals	Indiana: Lee and Shields 2010, Illinois: Wolters et al. 2009
Chip Seals	Montana: Baladi et al. 2002, Minnesota: Wood and Olson 2007, Indiana: Lee and Shields 2010, Canada: Chan et al. 2010, Illinois: Wolters et al. 2009
Slurry Seals	Canada: Croteau et al. 2005 [cape seal = slurry + chip seal], Chan et al. 2010, Illinois: Wolters et al. 2009
Asphalt Surface Treatment/Bituminous Surface Treatment (AST/BST)	Alaska: Mchattie 2001, Connor 1981, Canada: Mcleod 2000
Microsurfacing	Canada: Erwin and Tighe 2008, Croteau et al. 2005, Chan et al. 2010, Indiana: Lee and Shields 2010, Illinois: Wolters et al. 2009
Thin Overlays	
Bonded Wearing Courses	Indiana: Lee and Shields 2010, Illinois: Wolters et al. 2009, Canada: Chan et al. 2010
Interlayers	
In-place Recycling	Indiana: Lee and Shields 2010, Illinois: Wolters et al. 2009, Canada: Chan et al. 2010, Finland: Rantanen and Suikki 2009
Other treatments	Alaska: Berg and Esch 1983 [painted surface], Canada: Chan et al. 2010 [warm mix asphalt], Illinois: Wolters et al. 2009 [ultrathin whitetopping]

Baladi et al. (2002) report case studies of preventive maintenance in Montana, where the annual temperature may vary from above 100°F to less than -50°F. Based on the success of the initial investments on preventive maintenance (PM) in the mid 90's, the Montana Department of Transportation (DOT) has increased the budget for PM from $2 to $55 million. The Montana DOT has abandoned the old policy of constructing pavements and letting them go to rehabilitation or reconstruction. The treatments used as part of the PM program include (Baladi 2002):

- I-15 Chip seal (10 mm) in 1997 and crack seal in 1998 - after 3 years in good condition
- U.S. 287 Chip seal in 1991 - after 9 years in very good condition (ADT 4,100)

- MT 84: 4.6 mm HMA overlay in 1996 and latex modified chip seal in 1997 - after 3 years in good condition
- MT 69: 4.6 mm overlay and chip seal in 1996 - after 4 years in good condition

Lee and Shields (2010) present treatment guidelines for pavement preservation for Indiana Department of Transportation (INDOT). The following treatments for flexible pavements are used in Indiana (included in Table 3-1):

- Crack sealing (either filling with emulsion or routing and sealing with crumb rubber asphalt sealant)
- Fog seal
- Scrub seal (sand seal)
- Seal coat (chip seal)
- Flush seal (fog seal on the surface of chip seal)
- Microsurfacing
- Ultra-thin bonded wearing course (UBWC)
- Profile milling (treatment itself or preparation for thin HMA overlay)
- Thin HMA mill and fill (milling of the existing pavement with minor deterioration to a certain depth and filling it with a new HMA mixture to the original surface elevation
- Thin HMA overlay with profile milling (shallower milling depth than for “Thin HMA mill and fill”

Illinois Department of Transportation (IDOT) conducted first pavement preservation projects using appropriated funds in 2004 (Wolters et al. 2009). IDOT has created pavement preservation guidelines for local agencies. Guidance is provided in planning, financing, design, construction and maintaining local highway and street systems. The guidelines also include a detailed summary and treatment selection guide. The following treatment options are available for local agency use (included in Table 3-1):

- Crack filling
- Crack sealing
- Fog seals
- Sand seals
- Scrub seals

- Rejuvenators
- Slurry seals
- Microsurfacing
- Chip seals Pavement
- Cape seals
- Cold in-place recycling
- Hot in-place recycling
- Ultrathin bonded wearing course
- Ultrathin whitetopping
- Cold milling

The following list includes pavement preservation projects (number is parenthesis is the number or projects completed) in Illinois since fiscal year 2005 (Wolters et al. 2009):

- Bituminous surface treatments; 1-pass BST (6)
- Single-pass slurry seal (5)
- Single-pass microsurfacing (15)
- Two-pass microsurfacing (23)
- Cape seal; 1-pass BST and 1-pass microsurfacing (14)
- Half-SMART overlay; leveling binder and 1-pass BST (8)

Minnesota Department of Transportation (MNDOT) has rejuvenated its chip seal program with success (Wood and Olson 2007). MNDOT currently uses chip seals for both high and low trafficked roads. The average service life has increased from the 1990's from 5-7 years to 8-10 years. This increase is credited mainly to the use of larger chip size (from 100% passing the 0.25-in sieve to 100% passing the 3/8-in. sieve) and use of polymer modified asphalt. Other factors include proper mix design, clean pavement surface, single course of chips and proper construction techniques.

Chan et al. (2010) present pavement preservation treatments utilized by the Ministry of Transportation Ontario, Canada (MTO). The treatments include (included in Table 3-1):

- crack sealing
- slurry seal

- micro-surfacing
- chip seal
- ultra-thin bonded friction course (10 to 20 mm gap graded polymer modified HMA on polymer modified emulsified asphalt tack coat)
- fiber modified chip seal (chip seal with addition of fiberglass strands in the polymer modified emulsion hot mix patching and
- hot in-place recycling (HIR; heated surface is milled down to 40 - 50 mm, scarified material is rejuvenated and reprofiled) .

Croteau et al. (2005) studied the practice of chip seals and graded seals (called BST in Chapter 2) in Canada as well as internationally. Detailed instructions on how to select the aggregate and binder and their spread rate, prepare the site and schedule the work, select the equipment and the actual placement can be found from Croteau et al. (2005). The authors relate the performance of the seal coats in to following the aforementioned instructions, and do not give any other performance measures or service lives.

3.2 Expected Life of treatments

The service lives do not refer to how long the treatment lasts, but rather to how long the treatment serves the purpose for which it was placed, i.e. provides benefit (Peshkin et al. 2011). Further, treatment performance is measured in terms of the extension in service life imparted to the existing pavement by the treatment. These extensions can be used in cost effectiveness analysis. Peshkin et al. (2011) list service lives for several pavement preservation treatments (see Table 3-2). The ranges in Table 3-2 are collected from various sources, representing a variety of conditions and using different performance measures. Hence, according to Peshkin et al. (2011) the ranges may be based on perception rather than quantitative analysis.

The Ministry of Transportation of Ontario, Canada (Wei and Tighe 2004) reports service lives and costs for several treatments which are listed in Table 3-3.

Table 3-2. Expected performance of preservation treatments (Peshkin et al. 2011)

	Expected Performance	
Treatment	Treatment Life (yr)	Pavement Life Extension (yr)
Crack filling	2–4	NA
Crack sealing	3–8	2–5
Slurry seal	3–5	4–5
Microsurfacing		
Single course	3–6	3-5
Double course	4-7	4-6
Chip seal		
Single course	3–7	5–6
Double course	5–10	8–10
Ultra-thin bonded wearing course	7–12	NA
Thin HMA overlay		
Dense graded	5–12	NA
Open graded (OGFC)	6–12	NA
Gap graded (SMA)	NA	NA
Cold milling and thin HMA overlay	5-12	NA
Ultra-thin HMA overlay	4-8	NA
Hot in-place recycling		
Surface recycle and thin HMA overlay	6-10[b]	NA
Remixing and thin HMA overlay	7-15[c]	NA
Repaving	6–15	NA
Cold in-place recycling and thin HMA overlay Between 6–8 and	7–15[d]	NA
Profile milling	2–5	NA
Ultra-thin whitetopping	NA	NA

[a] Current indications are that SMA overlays perform the same or slightly better than dense-graded overlays.
[b] Range based on reported performance of surface recycle and subsequent surface treatment.
[c] Range based on reported performance of remixing and subsequent HMA overlay of unspecified thickness.
[d] Range based on reported performance of CIR and subsequent surface treatment (6 to 8 years) and CIR and subsequent HMA overlay of unspecified thickness (7 to 15 years).

Table 3-3. Service life and cost of treatments in Ontario (adapted from Wei and Tighe 2004)

Treatments	Life Year	Cost (CAD/lane/km)
Spray Patch	2	3.375
Machine Hot-Mix Patch	4	1.386
Chip Seals	5	10.125
Hot-Mix Patch	5	1.246
Rout and Seal	6	375
Mill and Patch 10%	6	2.450
Mill and Patch 20%	7	4.900
1 Lift Overlay	7	26.250

Ong et al. (2010) have developed long term pavement performance models for existing pavements as part of INDOT's pavement preservation program. The models for flexible pavements were developed for functional performance indicators such as pavement roughness and rut depth using regression analysis. Using pavement performance data from the Indiana pavement management system, models were developed for interstates/national highway system (Ong et al. 2010):

$$IRI = \exp 4.023 + 0.0040 AADTT * t + 0.0025 ANDX * t$$

$$PCR = \exp 4.572 - 0.0012 AADTT * t - 0.0023 ANDX * t$$

$$Rut = \exp -3.760 + 0.0095 AADTT * t + 0.0068 ANDX * t$$

where

IRI = international roughness index

PCR = pavement condition rating

Rut = rut depth (inch)

AADTT = average annual daily truck traffic

t = time (years)

ANDX = average annual freezing index (°F-days)

Ong et al. (2010) also developed short and long term performance models for the following pavement preservation treatments: crack seal, patching, microsurfacing and thin overlay. The concept of performance jump (PJ) and deteriorate rate reduction (DRR) is applied to determine the short term effectiveness. PJ is the difference between the condition before and after the treatment. In some cases, there might not be a discernible performance jump associated with the treatment but a reduction in the deterioration rate is experienced. Then it is more appropriate to use DRR as a measure of effectiveness of a preservation treatment. DRR is the difference between deterioration rate before and after treatment. The deterioration rate is determined as the difference in condition between two observations divided by the time between the observations. Table 3-4 shows the short term effectiveness models.

Table 3-4. Short Term Effectiveness Models for Asphalt Preservation Treatments (Ong et al. 2010)

Treatment	Short Term Effectiveness Models
Thin Preventive Maintenance Overlay	PJ_{IRI} = exp (-1.5748 x 10^{-8} IRI_b^2 – 0.01097 IRI_b + 4.7087) Fully restores PCR to 100 Fully restores rut depth to zero
Microsurfacing	PJ_{IRI} = 11.4995 + exp (0.01874 IRI_b) PJ_{PCR} = 20.07 – 0.198 PCR_b PJ_{Rut} = 0.03002 + 2.4805 Rut_b^2
Crack Seal	DRR_{IRI} = (1 – 3.7600 x 10^{-4} IRI_b)* $f'_b(t)$ PJ_{PCR} = 19.73 – 0.213 PCR_b No effect on rut depth
Patching	DRR_{IRI} = (1 – 3.5712 x 10^{-4} IRI_b)* $f'_b(t)$ Fully restores PCR to 100 No effect on rut depth
$_b$ = condition before treatment $f'_b(t)$ = deterioration before the treatment	

Certain preservation treatments, such as thin overlays and microsurfacing produce slower deterioration rates than the existing pavements. Therefore, long term effectiveness models of these pavement preservation treatments are needed (Ong et al. 2010). Using the pavement condition data from the pavement management databases, traffic data and work/contract information, long term performance models for the PM overlays and microsurfacing for Indiana pavement were developed: Table 3-5 shows the performance models in the form of:

$$y_i = \exp\ \beta_0 + \beta_1 *AADTT * t + \beta_2 *ANDX * t$$

where

y_i = the performance model (IRI, PCR or rut depth)

AADTT = average annual daily truck traffic

t = time (years)

ANDX = average annual freezing index (°F-days)

β_0 ,β_1 and β_2 = regression coefficients.

Table 3-5. Long Term Performance Models for Preservation Treatments (Ong et al. 2010)

Treatment	Functional Class	Performance Measure	Regression coefficients		
			β_o	β_1	β_2
Thin PM Overlay	Interstate/NHS	IRI (in/mile)	4.174	0.0064	0.0038
		PCR	4.571	-0.0075	-0.0048
		Rut Depth (in)	-3.760	0.0506	0.1730
	Non-NHS	IRI (in/mile)	4.223	0.0094	0.0072
		PCR	4.571	-0.0091	-0.0069
		Rut Depth (in)	-3.760	0.0604	0.1950
Microsurfacing	All	IRI (in/mile)	4.140	0.0045	0.0018
		PCR	4.578	-0.0030	-0.0058
		Rut Depth (in)	-3.760	0.0169	0.0457

With the pavement performance models and the triggers determined, it is possible to evaluate pavement preservation strategies using a "remaining service life" approach. The remaining service life is (Ong et al. 2010):

$$t = [\ln y_{treshold} - \ln y_i]/[\ \beta_1 *AADTT * t + \beta_2 *ANDX]$$

where $y_{treshold}$ = threshold value for the performance measure, and others as above. The remaining service life approach for strategy selection is given in Figure 3-1.

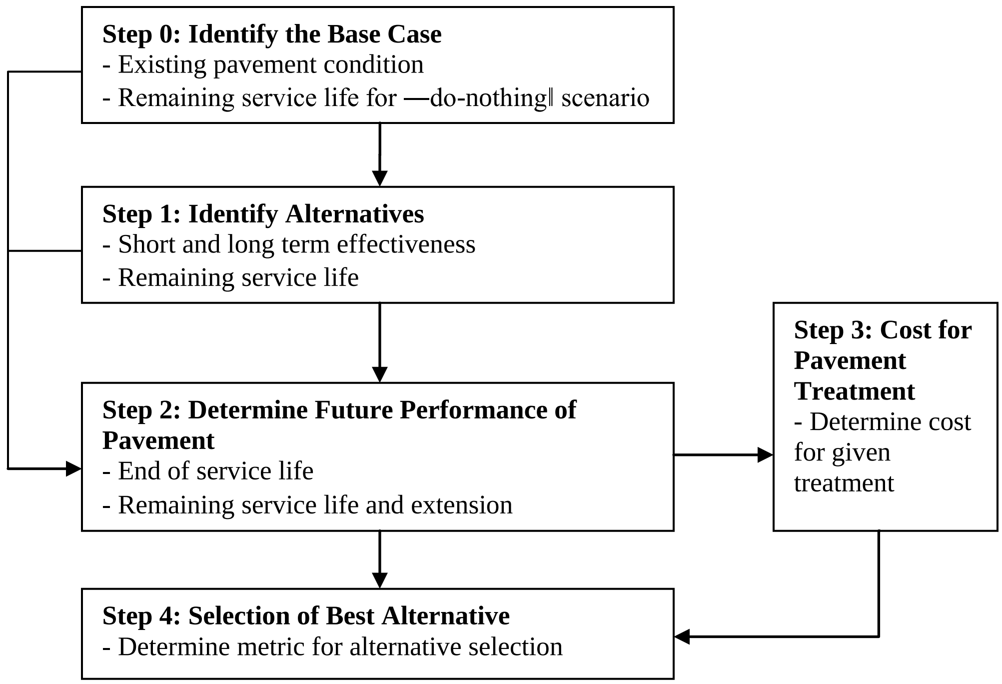

Figure 3-1. Remaining service life approach for strategy selection (Ong et al. 2010)

Rantanen and Suikki (2009) investigated use of in-place recycling and alternative treatments based on the experiences of the road agencies and contractors in the Southern Finland via road statistics, interviews and surveys. Table 3-6 represents the average service lives of three treatments comparing in-place recycling to a thin overlay. The trigger value for the service life is related to rutting (but not reported in more detail). There was not enough data to present service life of three consecutive in-place recycling applications or service life for roads with a smaller traffic volume. The analysis data agreed with current expert opinion in Finland that thin overlays last longer than in-place recycled road sections, and that one or two in-place recycling applications have about equal service life. I.e. the service life of twice recycled material is the same as once recycled material. Rantanen and Suikki (2009) conclude that even if the in-place recycled pavement does not last as long as a thin overlay or regular overlay, it is still cost effective in cases where limitations do not restrict its use (see sections 3.3 and 3.4).

Table 3-6. Service life based on rutting (in years), after Rantanen and Suikki (2009).

ADT	In-place recycling	2 consecutive in-place recycling (each)	Thin overlay
> 6000	6	6	8
3000 - 6000	7	7	9
1500 - 3000	8	8	10

Chan et al. (2010) list the following expected pavement extension lives (see Figure 1-1) for pavement preservation treatments in Ontario:

- crack sealing - 3 years
- slurry seal - 3 to 5 years
- micro-surfacing - 7 to 9 years
- chip seal - 4 to 6 years
- ultra-thin bonded friction course (10 to 20 mm gap graded polymer modified HMA on polymer modified emulsified asphalt tack coat) - high initial cost and limited use by the MOT
- fiber modified chip seal (chip seal with addition of fiberglass strands in the polymer modified emulsion) - new treatment which performance is currently monitored
- hot in-place recycling (HIR; heated surface is milled down to 40 - 50 mm, scarified material is rejuvenated and reprofiled) - 10 to 12 years similar to an HMA overlay

Table 3-7 summarizes treatment service lives found from literature and compares them with service lives from the survey (Chapter 2). The service lives from the survey and from the literature are in agreement. The values in Table 3-7 can be used as a guide when estimating service lives for Alaska. Selecting either low or high end value depends on site specific circumstances.

Table 3-7. Summary of pavement preservation treatment service lives

Treatment	Service life, years	
	Literature	Survey
Crack Sealing	3-8	3.4
Patching	4	3.6
Fog Sealing	-	3.4
Chip Sealing	3-10	5.6
Slurry Seals	3–5	4.6
AST/BST	-	6.0
Microsurfacing	3-9	6.0
Thin Overlays	5-12	6.8
Bonded Wear Courses	7–12	7.1
Interlayers		6.8
In-place Recycling	6-15	7.8

3.3 Problems encountered with using pavement preservation treatments

Cold regions have many challenges which may prevent the use of certain pavement preservation treatments. These challenges include issues with construction as well as issues while the treated road is in-service. Construction challenges include short and relatively (when compared to temperate regions) cold construction season, and in some cases poor availability of materials, construction equipment and skilled labor as well as long hauling distances (Doré and Zubeck, 2009). In-service challenges include usage of studded tires for winter traction, snow and ice removal operations and exposure to cold and moisture. Pavements in perennial frost areas are experiencing local failures due to degradation of the underlying permafrost.

Pavement failure modes and mitigation in cold regions are explained in detail by Doré and Zubeck (2009). Pavement preservation treatments and their applicability either preventing or mitigating failure modes in cold regions are summarized in Table 3-8. The "mitigation" in Table 3-8 indicates when a treatment *corrects* the defects caused by a certain failure mode. The "prevention" indicates when a treatment *aids in prevention* of a certain failure mode from happening. Table 3-8 is not inclusive but provides general guidelines on when and for what purpose to consider each treatment.

One of the challenges in cold regions is the aforementioned low temperature and its effects on the performance of pavement preservation treatments. Kim and Lee (2007) considered low temperatures in their research on performance of chip seals constructed with polymer modified emulsions (PME). They compared the performance of PME chip seals to those constructed with unmodified emulsion. The evaluation was based on aggregate retention, bleeding, rutting, and life-cycle cost analysis (LCCA). Three kinds of emulsion (CRS-2, CRS-2P, and CRS-2L) were used to fabricate samples in the laboratory and in the field. The results indicated that the PME's (CRS-2P and CRS-2L) enhance chip seal performance. This improvement is due specifically to the fast and improved adhesion of PME's and their ability to enhance the aggregate retention at low temperatures. The aggregate retention was measured at -20°C (-4°F) and at 4.4°C (40°F). Also, PMEs reduced bleeding and rutting. The performance data indicated that the use of PMEs can extend the service life of chip seals for more than two years. According to the LCCA, this extension is enough to make the use of PMEs cost-effective. The use of PMEs should be considered in Alaska.

Croteau et al. (2005) state that success of seal coat treatments is not only related to favorable weather conditions during the placement, but also the following weeks after the placement of the treatment. The traffic contributes to the embedment of the aggregate into the binder and the substrate, which do not happen if the pavement surface is cold. If the aggregate is not properly embedded into the substrate, snow plough damage may occur during the winter months. As mitigation for late season work, Croteau et al. (2005) suggest use of multi-layer systems with fine aggregate or use of premium binder.

Table 3-8. Primary uses of pavement preservation treatments relating to cold regions failure modes

Failure Mode	Crack Sealing	Patching	Fog Seals	Chip Seals	Slurry Seals	AST/BST	Microsurfacing	Thin Overlays	Bonded Wearing Courses	Interlayers	In-place Recycling
Thermal cracking (transverse)	m									m[3]	
Frost cracking (longitudinal)	m	p[1]			p[1]	p[1]	p[1]	p[1]	p[1]	m[3]	
Fatigue cracking	p[1]		p[2]	p[2]	p[1,2]		P[1,2]	P[1,2]	P[1,2]	m[3]	
Crack deterioration	p	m								m[3]	
Rutting -stud wear - permanent deformation								m	m		m m
Aging			p	p	p		p	p	p		m
Pavement disintegration due water, deicing, frost	p[1]	p[1]/m		p	p	p	p	p	p		m[4]
Potholes	p[1]	m									m[5]
Thaw consolidation of frozen soils in permafrost areas		m[6]				m[7]				p	

p = prevention, m = mitigation
[1] indirectly by keeping water out of pavement structure
[2] indirectly by reducing aging rate
[3] in some cases by reducing reflective cracking
[4] applies for pavement surface disintegration
[5] applies only for a small amount of patched potholes
[6] applies for small breaches
[7] AST/BST treated road can be reprofiled easier than treated with any HMA applications
Sources: Doré and Zubeck 2009, Rantanen and Suikki 2009, McLeod 2000

Weather may also limit the treatments used in cold regions. E.g. Lee and Shields (2010) state that crack sealing should not be conducted on wet surface due to problems with adhesion between the crack face and seal or fill material. They recommend an operation temperature of close to 40°F (on the warm side, due to INDOT specification of a minimum temperature of 40°F and the fact that cracks are wider the colder temperature is). The moisture limitations apply for fog seals and scrub seals as well. Fog seals, scrub seals, flush seals, chip seals and UBWC need to be applied at temperatures > 60°F, which is a temperature range that may not appear in parts of Alaska for weeks at a time even in summer. Microsurfacing should be applied at temperatures > 50°F, and not applied if there is a possibility that the finished product will freeze within 24 hours after application. Connor (1981) investigated BSTs in Alaska and concluded that treatments placed after August 20th (corresponds construction temperatures dropping below 5°C) fail due to loss of aggregate.

Peshkin et al. (2011) do not recommend the use of slurry seals (Type III) in deep freeze areas (deep freeze not defined by Peshkin et al. 2011). Ultrathin HMA pavement overlay, profile milling and ultra-thin white topping are only recommended provisionally.

As shown in Section 2.1, surface treatments and seals are not used under heavy studded tire usage. Instead, crack sealing, parching and thin overlays are common treatments followed by microsurfacing, bonded wearing courses and in-place recycling. Studded tire wear also had an effect on test section performance studied by Berg and Esch (1983). The test section included painted HMA surfaces as well as light colored and dark colored chip seals. The aim of the study was to investigate if permafrost degradation could be prevented with light colored surfaces. The yellow and white painted surfaces had the lowest pavement temperatures, but the effect was diminished by studded tire wear.

Rantanen and Suikki (2009) investigated applicability of in-place recycling in Finland. Two regional road agencies, one in Central and one in Southern Finland, wanted to expand the use of in-place recycling and wanted to investigate the limitations of the technique. The investigation was based on the experiences of the road agencies and contractors in the Southern Finland via road statistics, interviews and surveys. The situation in the rest of Finland was charted by conducting a literature review.

In-place recycling (called REM) has been used in Finland since 1991 and has recently become more popular due to many factors; mainly the lack of road maintenance funding. The capital cost of in-place recycling is reported lower when compared to an overlay (thin or regular HMA). In-place recycling of rutted wheel paths also became popular in early 1990s.

Common practice is to recycle the road surface on the main road network from 1 to 3 consecutive times. However, the expert opinion of the road authorities as well as the contractors is that 2 consecutive applications of in-place recycling is a maximum. The expert opinion was that recycled road surfaces rut faster than new overlays (no distinction of the cause of rutting was reported) and the risk for immediate failure increases especially for SMA mixtures.

Reported risks relating to this technique:

- Mix design: Too coarse or dry mixture leads to raveling and pot holes and increased traffic noise. Too fine or wet mixture leads to increased rutting and slick driving surface.
- Construction: Failures relate to inadequate warming of the old pavement mixture, too fast advancing speed or inadequate milling depth.
- The existing bitumen hardens with every warming event, which leads to decreased resistance against several failure modes.

Limitations of the technique include:

- In cases of significant raveling of the pavement surface, in-place recycling is not recommended.
- Problems have been observed in keeping the crown of the cross section at a correct grade when recycling lane by lane. In-place recycling causes rounding up of the pavement surface and as a consequence, a channel between the lanes.
- The technique is not suitable for narrow roads or roads with soft shoulders due to the size and weight of the equipment.
- The technique is not recommended for intersections or small parking lots or other small areas.
- The quality of the recycled mixture decreases with increasing amount of patches in the existing pavement.
- In-place recycling is not recommended for thin pavements. This is due to the risk that the unbound base course material gets mixed with the HMA.

Cost considerations associated with recycling include:

- Contractors consider the absolute minimum square area of a contract to be 10,000 m^2, with 15,000 m^2 as a recommended minimum size.
- For in-place recycling to be profitable for a contractor, the total size of contracts should be at least 1 to 1.5 million square meters annually.

3.4 Cost effectiveness

According to Peshkin et al. (2011), the cost of treatments depends on size and location of the project, severity and quantity of distress, the quality of treatment's materials, amount of surface preparation and degree of traffic control. Table 3-9 lists typical unit cost ranges and corresponding relative costs of preservation treatments. The costs represent the in-place costs of the treatments, exclusive of traffic control costs and any surface preparation costs. Peshkin et al. (2011) present a detailed treatment selection process including cost effectiveness analysis. However, they point out (valid for Alaskan condition) that the decision-making process includes many other factors, such as availability of qualified (and properly equipped) contractors and materials, anticipated level of traffic disruption and surface characteristics issues.

The ranges in Table 3-9 are not necessarily for cold regions. The costs could be higher due to longer transportation distances for equipment, materials and labor, and due to short construction season.

Table 3-9. Estimated treatment costs for preservation treatments (Peshkin et al. 2011)

Treatment	Relative Cost ($ to $$$$)	Estimated Unit Cost
Crack filling	$	$0.10 to $1.20/ft
Crack sealing	$	$0.75 to $1.50/ft
Slurry seal	$$	$0.75 to $1.00/yd^2
Microsurfacing (single-course)	$$	$1.50 to $3.00/yd^2
Chip seal (single-course)	$$(conventional)	$1.50 to $2.00/yd^2 (conventional)
Chip seal (single course)	$$$ (polymer modified)	$2.00 to $4.00/yd^2 (polymer modified)
Ultra-thin bonded wearing course	$$$	$4.00 to $6.00/yd^2
Thin HMA overlay (dense graded)	$$$	$3.00 to $6.00/yd^2
Cold milling and thin HMA overlay	$$$	$5.00 to $10.00/yd^2
Ultra-thin HMA overlay	$$	$2.00 to $3.00/yd^2
Hot in-place recycling (excluding thin HMA overlay for surface recycle and remixing types)	$$/$$$	$2.00 to $7.00/yd^2
Cold in-place recycling (excluding thin HMA overlay)	$$	$1.25 to $3.00/yd^2
Profile milling	$	$0.35 to $0.75/yd^2
Ultra-thin whitetopping	$$$$	$15.00 to $25.00/yd^2
Note: $ = low cost; $$ = moderate cost; $$$ = high cost; $$$$ = very high cost.		

Wei and Tighe lists treatment costs for Ministry of Transportation of Ontario. The costs can be found in Table 3-3. Wei and Tighe (2004) also present a decision tree for treatment selection based on the values found in Table 3-3.

Rantanen and Suikki (2009) list the costs for in-place recycling and costs for alternative treatments. The cost data is based on the experiences of the road agencies and contractors in the Southern Finland via road statistics, interviews and surveys. The unit prices are given in Table 3-10, and Table 3-11 gives the annual cost per unit area of each treatment based on the average service life (see Table 3-6).

Table 3-10. Treatment unit prices (after Rantanen and Suikki, 2009)

Technique	Price ($\$/m^2$)[1]
HMA 16[2]/20[3] in-place recycling	3.3
HMA 16[2]/100[3] overlay on existing surface[4]	6.2
Cold milling + HMA 16[2]/100[3] overlay	7.6
HMA 16[2]/80[3] thin overlay on heated and milled surface	5.6
SMA 11[2]/20[3] in-place recycling	3.5
SMA 16[2]/100[3] overlay on existing surface[4]	7.7
Cold milling + SMA 16[2]/100[3] overlay	9.0
SMA 16[2]/80[3] thin overlay on heated and milled surface	6.9

[1] converted from Euros; 1 Euro = 1.3 USAD in 2010

[2] maximum aggregate size (mm)

[3] amount of mixture added (kg/m^2)

[4] no milling

Table3-11. Treatment annual costs (after Rantanen and Suikki, 2009)

Annual cost $/m[2]	ADT		
	1500 - 3000	3000 - 6000	> 6000
HMA 16[2]/20[3] in-place recycling	$0.39	$0.48	$0.55
HMA 16[2]/20[3] in-place recycling - twice	$0.39	$0.49	$0.59
HMA 16[2]/100[3] overlay on existing surface[4]	$0.62	$0.72	$0.79
Cold Milling + HMA 16[2]/100[3] overlay	$0.74	$0.87	$0.95
HMA 16[2]/80[3] thin overlay on heated and milled surface	$0.56	$0.64	$0.70
SMA 11[2]/20[3] in-place recycling	$0.42	$0.51	$0.59
SMA 11[2]/20[3] in-place recycling - twice	$0.43	$0.53	$0.62
SMA 16[2]/100[3] overlay on existing surface[4]	$0.75	$0.88	$0.98
Cold milling + SMA 16[2]/100[3] overlay	$0.88	$1.03	$1.13
SMA 16[2]/80[3] thin overlay on heated and milled surface	$0.69	$0.79	$0.87

[1] converted from Euros; 1 Euro = 1.3 USAD in 2010

[2] maximum aggregate size (mm)

[3] amount of mixture added (kg/m[2])

[4] no milling

3.5 Other issues

There is a perception that the public will not support pavement preservation, but prefer the "worst-first" strategy. However, issues such as sustainability and use of green products or technologies are becoming driving market forces. Traffic safety affects directly the quality of life of road users. When these issues are considered, pavement preservation could be seen and marketed in a new light.

3.4.1 Sustainability

Chan et al. (2010) report that Ministry of Transportation Ontario (MTO) uses numerous innovative pavement preservation technologies that conserve aggregates, reduce GHG emissions, and minimize energy consumption. MTO's sustainability strategy is to implement these technologies on a larger scale, since they support a "zero-waste" approach and will assist in meeting the GHG reduction commitments. Also the triple-bottom line is addressed: Social, Economic and Environmental. Chan et al. (2010) recommend quantifying the benefits by life cycle cost analysis (economic) which utilizes PaLATE software (Pavement Life-cycle Assessment for Environmental and Economic Effect by University of California at Berkley) to assess GHG emissions and energy consumption.

MTO is also developing Green Pavement Rating System to quantify and encourage pavement sustainability (Chan et al. 2010). The rating system is based on the one developed by the University of Washington and CH2MHill (2011). The Greenroads rating system is a collection of sustainable roadway design and construction best practices. Each sustainable practice is assigned a point value according to its impact on roadway sustainability. There are 11 "Project Requirements" that must be done in order for a roadway to be considered a Greenroad:

- PR-1 Environmental Review Process
- PR-2 Lifecycle Cost Analysis
- PR-3 Lifecycle Inventory
- PR-4 Quality Control Plan
- PR-5 Noise Mitigation Plan
- PR-6 Waste Management Plan
- PR-7 Pollution Prevention Plan
- PR-8 Low Impact Development
- PR-9 Pavement Management System
- PR-10 Site Maintenance Plan
- PR-11 Educational Outreach

Green Paving Rating System could be implemented in Alaska to promote pavement preservation for pavement sustainability.

3.4.2 Traffic Safety

One of pavements' primary roles is to provide a *safe* driving surface. Yet, traffic safety is seldom, if ever considered in pavement management systems and decisions relating the selection of treatments. Erwin and Tighe (2008) investigated the effect of preventive maintenance techniques on road safety in York Region in northeast of Toronto, Ontario, Canada. The preventive maintenance techniques were microsurfacing and other resurfacing treatments. The study based on comparison of before and after treatment traffic accident data for a total of 40 sites. Erwin and Tighe (2008) determined that microsurfacing has a positive safety effect when applied at locations with an AADT > 3,000 veh/lane. This relationship was confirmed through data analysis to be statistically significant and sensitive to the treatment year data. The results were not as strong for resurfacing, although analysis revealed that resurfacing has a statistically significant safety effect where AADT is 3,000 - 6,999 veh/lane.

Before and after studies could also be conducted for pavement preservation sites in Alaska. The cost of crashes potentially reduced could be calculated using data by the National Highway Transportation Safety Board (Blincoe et al. 2002). Blincoe et al. (2002) provide estimates for dollar values of motor vehicle crashes.

3.4.3 Trends in asset management

Thirteen European countries (Belgium (Flanders), Denmark, Finland, France, Germany, Ireland, Lithuania, Netherlands, Norway, Slovenia, Sweden, Switzerland, and United Kingdom) are currently conducting a research program called Effective Asset Management Meeting Future Challenges (ERA-NET ROAD, 2011). The aim of the program is to improve technical, economical and sustainable performance of the European road network. It focuses on a cross asset approach, key performance indicators and the incorporation of environmental issues.

Out of the work currently in progress, the most interesting topic relating to pavement preservation is the ASCAM, Asset Service Condition Assessment Methodology (ERA-NET ROAD, 2011). The ASCAM will relate asset condition prediction to measures and network value. It will create a framework to connect existing asset management practices into a holistic, integrated cross asset, pro-active approach. It will relate technical and societal issues, like pavement degradation or failures in the “dynamic traffic management systems” to end-user service levels such as efficient traffic flow, safety, reliability of travel time, noise hindrance or environmental issues.

More specifically:

• Connect (technical) measures to end-user service levels

• Add value by connecting inspection and monitoring information to the necessary measures

• Compare maintenance strategies (measures and costs) in terms of end-user service level.

• Add relevant topics like "grand societal challenges" (mobility, climate change) to the end-user service levels

The work is anticipated to be completed by the end of 2012 (Finnra, 2011).

Sarkka and Talvitie (2008) investigated use of models among the road authorities in decision making and planning. These models included models relating to road procurement as well as maintenance and operation. The scope of work included surveys among the experts, administrators and users. According to the survey results, the models are not used widely. Reasons for the lack of utilizing the models are mainly the fact that the models are not required by the decision makers, and the authorities do not know how to use the models or their potential. However, the use models relating to road operation and maintenance is the most common amongst the all existing models in the industry.

The models relating to pavement planning include:

- HIBRIS; analysis software for maintenance and rehabilitation investments (considers current structures, condition, age, past maintenance/rehabilitation operations, effect of potential operation on condition and economics.
- PMS_Pro; model for pavement condition (rutting, roughness, other failure mechanisms, bearing capacity)
- TARVA; models predicting driving safety
- Life-cycle cost
- Models for user costs (IVAR)
- Job specific cost/benefit models
- Simulation models (Paramics, Hutsim, Dynameq)
- Models for noise and other environmental effects

Dietrich and Mannisto (2007) point out that the outcome of PMS_Pro, a list of potential road sections for treatment, ignores user costs as well as some of the owner costs. The authors suggest an optimization model that would produce a list of potential road sections with specific treatment techniques by minimizing the costs for the owner and the user. The model would help eliminating treating road sections too early or too late and consider combining jobs within one contract.

The object is to minimize the total rehabilitation/treatment cost over a time period for the PMS_Pro selected road sections within a region. The variables in the optimizing model are the timings of the operations for each road section or combination of sections. The optimization could be conducted using several methods, e.g. brute-force technique. The following factors should be considered:

- Effect of the length of the section to the cost.
- User costs due to construction
- Effect of early treatment to the remaining service life
- Effect of late treatment to user costs
- Effect of timing to the total cost.

Part of the optimization process (Dietrich and Mannisto, 2007) is the use of road condition prediction models. These models predict future deterioration based on past measurements as well as predict the effect of future maintenance/rehabilitation events. The authors state that the current models (part of PMS_Pro and HIBRIS) apply at a network level. Therefore, they are not accurate enough to predict the road condition for a certain road section selected for treatment. The need in Finland is to develop accurate models for job specific predictions.

4. Conclusions and Recommendations

4.1 Conclusions

On the basis of the literature review and the survey, the following conclusions were made:

- Pavement preservation treatments, Crack Sealing, Patching, Fog Seals, Chip Seals, Slurry Seals, AST/BST, Microsurfacing, Thin Overlays, Bonded Wearing Courses, Interlayers and In-place Recycling, are used in cold regions and have potential for use in Alaska.
- Crack sealing and patching are the most extensively used pavement preservation techniques and their use in Alaska should be continued.
- Use of chip seals, fog seals, slurry seals should be considered job specifically. Construction is limited to temperatures > 60°F, which creates a problem for many Alaskan locations. These treatments are not used in other cold regions with heavy studded tire usage.
- Traffic volume affects applicability of certain treatments. Table 2-1 suggests recommended traffic levels for pavement preservation treatments for Alaska.
- The service life of the treatments varies from about 3 years to 12 years. The literature and the survey agree that microsurfacing and thin overlays have the longest service life.
- Many regions have dedicated budgets for pavement preservation. Comments typically state the need for more funds.
- Most regions use several performance measures to determine trigger values for the due time of pavement preservation treatments. IRI, rutting, cracking and expert opinion are used extensively.
- The costs of treatments vary from a region to another as well as from project to another. Cost data from the survey is given in Table 2-4 and from the literature in Tables 3-7 to 3-9.
- Other issues than cost effectiveness can be considered when marketing pavement preservation. These issues include sustainability, green products and technologies and traffic safety.

4.2 Recommendations

4.2.1 Recommendations for Implementation

On the basis of the data and conclusions, the following recommendations for implementation are made:

- The data and conclusions presented here should be considered when preparing a Pavement Preservation Road Map for Alaska.

- Green Paving Rating System explained in Section 3.4.1 could be implemented in Alaska to promote pavement preservation for pavement sustainability.
- Pavement preservation should be included in AKDOT&PF's Asset Management Strategy.

4.2.2 Recommendations for Research

Several pavement preservation issues need further research in Alaska. The list presented here is limited to the items that came up during the survey and the literature review reported here:

- The great variability of pavement preservation treatment service lives warrant further research about affecting factors and predicted service lives for Alaskan conditions.
- Treatment cost information should be collected from past Alaska projects for cost effectiveness analysis purposes.
- In order to study reduction in traffic accidents due to a pavement preservation treatment, before- and-after studies could be conducted for preservation sites in Alaska.

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6.0 Appendices

6.1 Survey Form

Pavement Preservation in Cold Regions

Q1 Please fill in your contact information.

Name: (1)
Company: (2)
Address1: (3)
Address2: (4)
City/Town: (5)
State/Province: (6)
Zip/Postal Code: (7)
Country: (8)
Email Address: (9)
Phone Number: (10)

Q2 Position (e.g. pavement engineer or professor):

Q3 What area/region do your answers apply (could be a country or smaller area)?

Q4 To what extent are the listed techniques used in your area?

	Extensively (1)	In Special Cases (2)	Never (3)
Crack Sealing (1)	❍	❍	❍
Patching (2)	❍	❍	❍
Fog Seals (3)	❍	❍	❍
Chip Seals (4)	❍	❍	❍
Slurry Seals (5)	❍	❍	❍
AST/BST (6)	❍	❍	❍
Microsurfacing (7)	❍	❍	❍
Thin Overlays (8)	❍	❍	❍
Bonded Wearing Courses (9)	❍	❍	❍
Interlayers (10)	❍	❍	❍
In-place Recycling (11)	❍	❍	❍
Other (12)	❍	❍	❍

Q5 Are the treatments repeated? If so, how often are they repeated?

	Only one application (1)	Every 4 years (2)	Every 3 years (3)	Every 2 years (4)	Annually (5)	More often (6)
Crack Sealing (1)	❍	❍	❍	❍	❍	❍
Patching (2)	❍	❍	❍	❍	❍	❍
Fog Sealing (3)	❍	❍	❍	❍	❍	❍
Chip Seals (4)	❍	❍	❍	❍	❍	❍
Slurry Seals (5)	❍	❍	❍	❍	❍	❍
AST/BST (6)	❍	❍	❍	❍	❍	❍
Microsurfacing (7)	❍	❍	❍	❍	❍	❍
Thin Overlays (8)	❍	❍	❍	❍	❍	❍
Thin Bonded Wearing Courses (9)	❍	❍	❍	❍	❍	❍
Interlayers (10)	❍	❍	❍	❍	❍	❍
In-place Recycling (11)	❍	❍	❍	❍	❍	❍
Other (12)	❍	❍	❍	❍	❍	❍

Q6 What is the average service life of the treatment used?

	1-2 years (1)	3-4 years (2)	5-6 years (3)	7-8 years (4)	9-10 years (5)
Crack Sealing (1)	❍	❍	❍	❍	❍
Patching (2)	❍	❍	❍	❍	❍
Fog Seals (3)	❍	❍	❍	❍	❍
Chip Seals (4)	❍	❍	❍	❍	❍
Slurry Seals (5)	❍	❍	❍	❍	❍
AST/BST (6)	❍	❍	❍	❍	❍
Microsurfacing (7)	❍	❍	❍	❍	❍
Thin Overlays (8)	❍	❍	❍	❍	❍
Bonded Wearing Courses (9)	❍	❍	❍	❍	❍
Interlayers (10)	❍	❍	❍	❍	❍
In-place Recycling (11)	❍	❍	❍	❍	❍
Other (12)	❍	❍	❍	❍	❍

Q7 Does your agency (or the agency in your area) have a separate dedicated budget for pavement preservation?

- ❑ Yes (1)
- ❑ No (2)
- ❑ I don't know. (3)
- ❑ Comment (4) ____________________

Q8 About when were these techniques used for the first time by your agency? Give year.

Crack Seals (1)
Patching (2)
Fog Seals (3)
Chip Seals (4)
Slurry Seals (5)
AST/BST (6)
Microsurfacing (7)
Thin Overlays (8)
Thin Bonded Wearing Courses (9)
Interlayers (10)
In-place Recycling (11)
Other (12)

Q9 Which performance measures do you use to evaluate pavement preservation treatments?

- ❑ IRI (1)
- ❑ Rutting (2)
- ❑ Cracking (3)
- ❑ Expert Opinion (4)
- ❑ Other (5) ____________________

Q10 Which pavement preservation method(s) do you use in these conditions?

	Crack Sealing (1)	Patching (2)	Fog Sealing (3)	Chip Sealing (4)	Slurry Seals (5)	AST/ BST (6)	Microsurfacing (7)	Thin Overlays (8)	Bonded Wear Courses (9)	Interlayers (10)	In-place Recycling (11)	Other (12)
ADT 200-1500 (1)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
ADT 500-2500 (2)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
ADT 1000-6000 (3)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
ADT >6000 (4)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Heavy studded tire usage (5)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Moist climate (6)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Late season for application (7)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑
Other (8)	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑

Q11 What was the average cost for each treatment in 2010 US dollars (give unit; e.g. USD/m2 or USD/road km)?

Crack Sealing (1)
Patching (2)
Fog Sealing (3)
Chip Sealing (4)
Slurry Sealing (5)
AST/BST (6)
Microsurfacing (7)
Thin Overlays (8)
Bonded Wearing Courses (9)
Interlayers (10)
In-place Recycling (11)
Other (12)

Q12 Do you have performance models, performance data, or relevant publications for any of these techniques? Describe or give a reference; don't leave out references not in English.

Crack Sealing (1)
Patching (2)
Fog Seals (3)
Chip Seals (4)
Slurry Seals (5)
AST/BST (6)
Microsurfacing (7)
Thin Overlays (8)
Bonded Wearing Courses (9)
Interlayers (10)
In-place Recycling (11)
Other (12)

Q13 Write here any other information that you would like to contribute to the research.

End Thank you for taking the survey. Go back to edit your answers or click "next" to submit.

6.2 Survey responders

Tremblay Guy	Manager Direction du Laboratoire des chaussées	Transports Québec	Québec	Canada
Joseph Ponniah	Senior pavement Research Engineer	Ministry of Transportation	Ontario	Canada
Jim Horn	Pavement engineer	AK DOT&PF	Alaska	USA
Masayuki Kaneko	Research engineer	Civil Engineer Research Institute for Cold Region	Hokkaido	Japan
Jesper Elsander	Pavement development engineer	Trafikverket		Sweden
D.J. Swan	Senior pavement engineer	ARA	ON	Canada
John Emery	Pavement Engineer and Professor	Shiloh Canconstruct Limited	Ontario	Canada
Johnny M Johansen	Consultant engineer	ViaNova Plan og Trafikk AS		Norway
Torfason	Pavement engineer	Hofdi Asphalt Plant		Iceland
Hugh	Construction Services Engineer	Donovan	Alberta	Canada
David Palsat	Senior Vice President, Transportation Practice &Western Senior Pavements Engineer.	EBA Engineering Consultants Ltd.	Alberta	Canada
Mike Oliver	Associate Chief Geotechnical and Pavement Engineer	Ministry of Transportation and Infrastructure	BC	Canada
Nils	Development Manager	Ulmgren		Sweden
Blomberg Timo	Technical manager	Nynas Oy		Finland
Donaldson MacLeod	Highway engineer	Donaldson MacLeod	On	Canada
Ragnar Evensen	pavement engineer	ViaNova Plan og Trafikk AS		Norway
Paul Lum	Pavement Engineer	Lafarge	Ontario	Canada
Blaine Morien	Manager - Technical Services and Marketing	Pounder Emulsions, A division of Husky Oil Limited	Saskatchewan	Canada
Terhi Pellinen	Professor	Aalto University		Finland
Steve Goodman	Pavement Engineer	AME Materials Engineering	Ontario	Canada

Carl A. Lenngren	Pavement Design Research and Development Specialist	Svevia		Sweden
Tara Liske	Surfacing Materials Engineer	Manitoba DOT	Manitoba	Canada
Safwat Said	Researcher	VTI		Sweden
Erik Nielsen	Senior researcher	Danish Road Directorate		Denmark
Chuck McMillan	Pavements Engineer	Alberta Transportation	Alberta	Canada
Katri Eskola	Expert of asphalt pavements	Finnish Transport Agency		Finland
paulette Hanna	Pavement Eng	WisDOT	wi	usa
Gary Kuhl	Pavement Management Engineer	Utah DOT	UT	USA
Anne Emidy	Assistant Highway Management Engineer	MaineDOT	ME	USA
Eric Thibodeau	Pavement Management Chief	NHDOT	NH	USA
Blair Lunde	Pavement Management Engineer	SDDOT	SD	USA
Michael Rossi P.E.	Civil Engineer II, Pavement Management Unit	NYSDOT	New York	United States
Hainian Wang	Professor	Chang'an University	Shaanxi	China
Gao Guodong	Pavement master	Chang'an university	Shan'xi	China
Ting Peng	Professor	Chang'an University	Shaanxi	China
Taina Rantanen	Designer	Sito Tampere Oy		Finland
Jiupeng Zhang	Assistant professor	Chang'an University	Shaanxi	China
Ingemar Gustafsson	Project Manager	Trafikverket, Tvusv		Sweden
Marcus Larsson (ML) och Georg Danielsson (GD)	ML: Beläggningsspecialist GD: Projektledare Beläggning	ML: Trafikverket Investering, Teknik och miljö Nord		Sweden
Liyan Shan	Assistant professor	Harbin Institute of Technology	Heilongjiang	China
Huining Xu	Ph.D Candidate	Harbin Institute of Technology	Heilongjiang	China PR
Sigang Wu	Professor	Harbin Institute of Technology	Heilongjiang	China
Tan Yiqiu	Professor	Harbin Institute of Technology	Heilongjiang Province	P.R.China

6.3 Detailed survey results

Pavement Preservation in Cold Regions - Survey Report

07/11/2011

1. Please fill in your contact information.

Name:	Company:	Address1:	Address2:	City/Town:	State/Province:	Zip/Postal Code:	Country:	Email Address:	Phone Number:
Tremblay Guy	Transports Québec	930 Chemin Sainte Foy		Québec	Québec	G1s 4X9	Canada	guy.tremblay@mtq.gouv.qc.ca	418 643 6618 (4001)
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John Emery	Shiloh Canconstruct Limited	7667 Old Church Road		Caledon	Ontario	L7E 0P5	Canada	shilohcanconstruct@gmail.com	905 880 0510
Johnny M Johansen	ViaNova Plan og Trafikk	POBox 434		Sandvika		NO-1302	Norway	jmj@vianova.no	+4767817000

	AS								
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Paul Lum	Lafarge	7880 Keele Street		Concord	Ontario	L4K 4G7	Canada	paul.lum@lafarge-na.com	4167067373
Blaine Morien	Pounder Emulsions, A division of Husky	806-50th Street East		Saskatoon	Saskatchewan	S7K 0X6	Canada	Blaine.Morien	1-306-955-7905

	Oil Limited								
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Anne Emidy	Maine DOT	16 State House Station		Augusta	ME	04364	USA	anne.emidy@maine.gov	207-624-3303

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Michael Rossi P.E.	NYSDOT	50 Wolf Road	Pod 32	Albany	New York	12232	United States	mrossi@dot.state.ny.us	518 457-7046
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Gao Guodong	Chang'an university	Key Laboratory for Special Area Highway Engineering of Ministry of Education, Chang’an University, Xi’an, Shaanxi, China,		Xi'an	Shan'xi	710064	China	guodong222@yahoo.com.cn	15891422865
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g	ity	2nd Circular Road							
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Marcus Larsson (ML) och Georg Danielsson (GD)	ML: Trafikverket Investering, Teknik och miljö Nord	Box 809	Sundsbacken 2-4	Luleå		971 25	Sweden	marcus.larsson@trafikverket.se georg.danielsson@trafikverket.se	ML: 0702183132 GD: 0703243788
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Sigang Wu	Harbin Institute of Technology	No.73Huanghe Road, Harbin, China		Harbin	Heilongjiang	150090	China	wusigang@163.net	13804515015
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Statistic	Value
Total Responses	43

2. Position (e.g. pavement engineer or professor):

Text Response
Manager Direction du Laboratoire des chaussées
Senior pavement Research Engineer
pavement engineer
research engineer
pavement development engineer
Senior pavement engineer
Pavement Engineer and Professor
consultant engineer
Pavement engineer
Construction Services Engineer
Senior Vice President, Transportation Practice &Western Senior Pavements Engineer.
Associate Chief Geotechnical and Pavement Engineer
Development Manager
Technical manager
highway engineer
pavement engineer
Pavement Engineer
Manager - Technical Services and Marketing
Professor
Pavement Engineer
Pavement Design Research and Development Specialist
Surfacing Materials Engineer
Researcher
Senior researcher
Pavements Engineer
expert of asphalt pavements
pavement Eng
Pavement Management Engineer
Assistant Highway Management Engineer
Pavement Management Chief
Pavement Management Engineer
Civil Engineer II, Pavement Management Unit
Professor

pavement master
professor
Designer
assistant professor
Project Manager
ML: Beläggningsspecialist GD: Projektledare Beläggning
assistant professor
Ph.D Candidate
Professor
professor

Statistic	Value
Total Responses	43

3. What area/region do your answers apply (could be a country or smaller area)?

Text Response
Province of québec
Ontario
State of Alaska
state
Sweden
Canada
Canda, Colombia and China
Norway
Reykjavik area
City of Edmonton
Western and northern Canada
Province of BC
Sweden
Finland
Northern Canada
Norway
Ontario
Western Canada
Finland
Ontario, Canada
Sweden (National Level)
Province - Manitoba
Sweden
Denmark (state network level)
Province
country
Dane County
Statewide
State of Maine
New Hampshire (New England)
Statewide
New York State

Country
Tibet China
Shaanxi
Region Pirkanmaa
Shaanxi province
Jönköpings Region
ML: Nationwide (but mainly Norr och Västerbottens Regions) GD: Norrbottens Region
Heilong Jiang
Heilongjiang Province
Heilongjiang Jilin Liaoning
Northeast of China

Statistic	Value
Total Responses	43

4. To what extent are the listed techniques used in your area?

#	Question	Extensively	In Special Cases	Never	Responses
1	Crack Sealing	36	5	2	43
2	Patching	37	6	0	43
3	Fog Seals	2	25	13	40
4	Chip Seals	18	18	6	42
5	Slurry Seals	9	13	18	40
6	AST/BST	12	11	15	38
7	Microsurfacing	10	19	12	41
8	Thin Overlays	21	20	1	42
9	Bonded Wearing Courses	12	14	11	37
10	Interlayers	5	18	14	37
11	In-place Recycling	19	21	1	41
12	Other	1	4	0	5

Other
ECF Enrobé coulé à froid
Asphalt concrete
Full Depth Reclamation with stabilization
Rejuvenating Seals
Milling

Statistic	Crack Sealing	Patching	Fog Seals	Chip Seals	Slurry Seals	AST/ BST	Microsurfacing	Thin Overlays	Bonded Wearing Courses	Interlayers	In-place Recycling	Other
Total Responses	43	43	40	42	40	38	41	42	37	37	41	6

5. Are the treatments repeated? If so, how often are they repeated?

#	Question	Only one application	Every 4 years	Every 3 years	Every 2 years	Annually	More often	Responses	Mean
1	Crack Sealing	9	7	5	2	8	3	34	
2	Patching	10	3	5	2	12	4	36	
3	Fog Sealing	20	1	1	1	2	1	26	
4	Chip Seals	19	4	1	1	1	1	27	
5	Slurry Seals	10	4	2	1	1	1	19	
6	AST/BST	16	1	0	2	1	0	20	
7	Microsurfacing	15	3	2	2	1	0	23	
8	Thin Overlays	23	6	0	0	1	0	30	
9	Thin Bonded Wearing Courses	19	1	0	0	1	0	21	
10	Interlayers	15	2	1	0	1	0	19	
11	In-place Recycling	26	2	2	1	1	0	32	
12	Other	1	1	0	0	1	0	3	

Other
depending the needs
Asphalt concrete
Full depth reclamation with stabilization
as needed

Statistic	Crack Sealing	Patching	Fog Sealing	Chip Seals	Slurry Seals	AST/ BST	Microsurfacing	Thin Overlays	Thin Bonded Wearing Courses	Interlayers	In-place Recycling	Other
Total Responses	34	36	26	27	19	20	23	30	21	19	32	5

6. What is the average service life of the treatment used?

#	Question	1-2 years	3-4 years	5-6 years	7-8 years	9-10 years	Responses	Weighted average
1	Crack Sealing	14	13	6	3	0	36	3.4
2	Patching	11	15	7	1	1	35	3.6
3	Fog Seals	7	12	2	2	0	23	3.4
4	Chip Seals	2	9	5	7	4	27	5.6
5	Slurry Seals	2	7	6	3	0	18	4.6
6	AST/BST	2	3	4	5	3	17	6.0
7	Microsurfacing	2	3	9	5	4	23	6.0
8	Thin Overlays	1	5	8	7	10	31	6.8
9	Bonded Wearing Courses	0	3	4	7	6	20	7.1
10	Interlayers	0	3	5	5	5	18	6.8
11	In-place Recycling	0	4	6	4	18	32	7.8
12	Other	1	0	0	0	2	3	6.8

Other
Asphalt concrete
Full depth reclamation with stabilization
it depends

Statistic	Crack Sealing	Patching	Fog Seals	Chip Seals	Slurry Seals	AST/ BST	Microsurfacing	Thin Overlays	Bonded Wearing Courses	Interlayers	In-place Recycling	Other
Total Responses	36	35	23	27	18	17	23	31	20	18	32	4

7. Does your agency (or the agency in your area) have a separate dedicated budget for pavement preservation?

#	Answer		Response	%
1	Yes		23	59%
2	No		13	33%
3	I don't know.		3	8%
4	Comment		5	13%

Comment
Also consider in the general planification
Not Enough Money Provided
is part of overlay program but assigned to preservation
VTI is research institute not responsible for roads
Pavement Management System in place - It performs the optimization

Statistic	Value
Total Responses	39

8. About when were these techniques used for the first time by your agency? Give year.

Crack Seals	Patching	Fog Seals	Chip Seals	Slurry Seals	AST/ BST	Microsurfacing	Thin Overlays	Thin Bonded Wearing Courses	Interlayers	In-place Recycling	Other
before 1980								2000		1995	
3-4 yrs after the construction	8	8-10	8-10	8-10	12-14	12-14	12-14		12-14	15	
> 30 years ago	> 30 years ago	>30 years ago	> 30 years ago	> 30 years ago	> 20 years ago	> 20 years ago	> 30 years ago	> 20 years ago	> 20 years ago	> 20 years ago	
forever	forever	not used	since the 70's	not used	since the 70's	since the late 90's	last 10 years	not used	not used	hot in place for 20 years; cold in place for 5 years	Full depth reclamation for 10 years
70s	50s				70s		70s			80s	
Way back	Way back	Way back	Way back	1980	Way back		Way back	1995		1990	
1980	1980				1980	1995	1990			1995	
before my time	before my time		before my time	before my time		1989	before my time			before my time	
1990	1950	1970	1972	1980	1970	na	1995	1985	1985	1982	

always	always	mid 1980s	mid 1980s			approx. 1990	approx. 1960	approx. 1990		mid 1980s	
1970s	?always		1960s	1990		1990	2005			2008	
years ago	years ago	years ago	years ago	years ago		years ago	years ago	years ago		years ago	
for ever	for ever	kind of stopped using	for ever	seldom		recently	for ever	recently	seldom	recently	
Unknown	Unknown		2004			2006	Longtime	1998	1980s	1990s	
Pre 1970	Pre 1970	1980	1980	1980		1995	1995	2000	2000	1995	
1996	1995	2006	1999	1992		1995	2000	2002	2004	2006	
1980's	1980's									1991	
1983	1975	2005	1960	1985	1983		1965	2004	1995	1992	
1980s	1980s		1980s				1990s	2000s	2000s	1990s	
1990									2001	2009	
1970s	1970s	1998	1980s	1981	1980s	2005	1970s	2000s	2007	2003	
						1999		1195		1995	
						2000	2004	2000	2009	1988	
							1989	1991		1991	
							2005			2000	
						2001					

Statistic	Value
Total Responses	26

9. Which performance measures do you use to evaluate pavement preservation treatments?

#	Answer		Response	%
1	IRI		32	84%
2	Rutting		33	87%
3	Cracking		29	76%
4	Expert Opinion		27	71%
5	Other		3	8%

Other
FWD
MicroPaver or Equivalent
pavement strength

Statistic	Value
Total Responses	38

10. Which pavement preservation method(s) do you use in these conditions?

#	Question	Crack Sealing	Patching	Fog Sealing	Chip Sealing	Slurry Seals	AST/BST	Microsurfacing	Thin Overlays	Bonded Wear Courses	Interlayers	In-place Recycling	Other	Responses
1	ADT 200-1500	22	25	11	17	11	7	8	15	5	3	15	1	140
2	ADT 500-2500	23	23	12	14	9	4	8	19	7	3	21	1	144
3	ADT 1000-6000	23	23	8	10	5	6	14	19	11	5	18	1	143
4	ADT >6000	24	22	2	6	4	3	13	16	14	4	15	1	124
5	Heavy studded tire usage	13	12	1	4	3	2	6	12	7	3	6	0	69
6	Moist climate	11	13	3	7	6	5	6	11	6	6	9	0	83
7	Late season for application	10	13	1	2	2	1	3	5	1	1	4	0	43
8	Other	0	0	0	0	0	0	0	0	0	1	0	0	1

Other
Full depth reclamation with stabilization
ways for pedestrian and bicycles

Statistic	ADT 200-1500	ADT 500-2500	ADT 1000-6000	ADT >6000	Heavy studded tire usage	Moist climate	Late season for application	Other
Total Responses	28	29	28	27	18	17	16	2

11. What was the average cost for each treatment in 2010 US dollars (give unit; e.g. USD/m2 or USD/road km)?

Crack Sealing	Patching	Fog Sealing	Chip Sealing	Slurry Sealing	AST/ BST	Microsurfacing	Thin Overlays	Bonded Wearing Courses	Interlayers	In-place Recycling	Other
2-4 /m	30-40 /m2	11 /m2	10 /m2	11 /m2	16 /m2	7 /m2	20 /m2	45 /m2		50 /m2	
2.50	3.75	1.50		2.75		3.25	17.50	25.75		25-35	
$10 per lineal metre	$20 per square metre				$10 per square metre		$120,000 per lane km			$100,000 per lane km	
3.40 USD/ m	37.00 USD/ m	1.80 USD / m2	5.80 USD/ m2			5.60 USD/ m2				24.80 USD/ m2	
5000/lane mile	8,000 /lane mile	Varies	13,000/lane mile	Varies		28,000/ lane mile	40,000/ lane mile				
$7,500/mile		$17,000/mile				$91,800 /mile	$150,000/mile			$500,000/mile	
$0.90/ lb	????		$2.15/ SY			$3.00/SY	$2.70/SY	$6.00/SY	$10.00/SY	$6.00/SY	
$5k / Lane mile (LM)		$10k / LM	$20k / LM	$15k / LM		$40k / LM	$50k / LM	$50k / LM		$120k / LM	
250	150	15	16	16	13		60	65 (incl. surface planing)	85	45	Note: SEK per sq m
60	70		22				90	60	60 (inter	60	

									layer cost only)		
2$/m2	2$/m2	1$/m2	2$/m2	1.5$/m2	1$/m2	4$/m2	7$/m2		8$/m2		
	300/km				50000/km	75000/km	225000/km			250000/km	
										~3 USD/m2	

Statistic	Value
Total Responses	13

12. Do you have performance models, performance data, or relevant publications for any of these techniques? Describe or give a reference; don't leave out references not in English.

Crack Sealing	Patching	Fog Seals	Chip Seals	Slurry Seals	AST/BST	Microsurfacing	Thin Overlays	Bonded Wearing Courses	Interlayers	In-place Recycling	Other
y	no					no	no	no	no	yes	
Yes CTAA						Yes CTAA	Yes CTAA			Yes CTAA	
Standard Specs	Standard specs				Standard Specs					Standard specs	
no	no	no	no	no		no	no				
Förebyggande bel.uh	VVTBT	none	AMA, VVTBT	Handbok	AMA, VVTBT		AMA, VVTBT	AMA, VVTBT	none	AMA, VVTBT	
yes	yes		yes				yes	yes	yes	yes	
[15] Al-Hadidy AI, Tan Yi-											

qiu, Dong Ze-jiao, Wang Jia-ni. Preparation of low-cost waterproofing materials. Journal of Harbin Institute of Technology(New Series),2008,4. （EI ）											
					TRB papers	Internal reports					
							Asphalt Institute	Asphalt Institute		Wirtgen Cold Recycling Manual	
								http://oracle.toronto.ara.com/Library/ICMP			

								/7th%20Calgary/24-70.pdf			
										Uusio päällysteiden käyttö päällysteiden ylläpidossa, Tiehallinnon sisäisiä julkaisuja 56/2009	
										Uusio päällysteiden käyttö päällysteiden ylläpidossa	http://alk.tiehallinto.fi/julkaisut/pdf2/3201148-v-sivukaltevuustunnusluku.pdf

Statistic	Value
Total Responses	12

13. Write here any other information that you would like to contribute to the research.

Text Response
Alaska does not perform pavement preservation per se. The treatments in the survey are performed as preventative maintenance, routine maintenance, corrective maintenance, and planned rehabilitation. Rutting and IRI drive the decisions for maintenance - attempts are under way to move into a planned preventative system.
There are many Canadian publications available through the Transportation Association of Canada on the way pavement preservation is addressed.
Suggest the CTAA Proceedings and CUPGA Workshops have a lot of current information of relevance, particularly as parts of Canada are very similar to Alaska in climate and pavements technology. My responses are based mainly on experience in Southern Ontario. Costing information is very "volatile" at this time due to the current energy (petroleum) supply issues. Costing data for Ontario is generally (historically) available from the Ontario Ministry of Transportation and quite similar to US States bordering Eastern Canada (See ENR for instance).
Alberta Transportation published a unit price report on their web site http://www.transportation.alberta.ca/694.htm The Canadian Technical Asphalt Association Proceedings are an excellent source of information on asphalt technology especially in cold climates http://www.ctaa.ca/; Also the proceedings of the Transportation Association of Canada http://www.tac-atc.ca/
We use thin overlays and Hot in Place recycling as the main choice for pavement rehab. For preservation we use graded aggregate seal, crack sealing and patching. We have tried all other to limited success such as microsurfacing, chip sealing, slurry seals, fog seals but we would not normally use these. The choice is mainly expert opinion. We do have tools available to assist expert opinion such as pavement condition surveys that collect network data on IRI, rutting, distress.
It is difficult to give exact data and prices. The national road network maintenance is handled by a Pavement Management System that optimizes a priority list each year depending on inventory of road network, ADT, negotiated price for standard maintenance operations offered in regional contracts and available funds. When a preventive maintenance is taken it is also depending on forecast of needed bearing capacity etc. An example : Remix is normally only used as a on the old wearing course in order to produce a binder course for a new surface layer (which can be either Thin HMA layers optimized for noise reducing capability). The PMS has been developed over many years and is still being improved. Traffic delay costs are included and do something results in night time maintenance operations which is more costly and perhaps have a little less durable performance.
We do not use performance models for preservation treatments per se. Our preservation guidelines provide some range of life. For some single type applications (i.e sealcoat) it is considered to last until the pavement requires rehabilitation otherwise. Our preservations guidelines are available online at http://www.transportation.alberta.ca/Content/docType233/Production/gappts.pdf
Answers cover public roads only. "Crack sealing" according your definition is not used in Finland. In Finland "Crack sealing" means sealing cracks < 30 mm by hot bitumen. Used in hot mix paved roads (ADT > 2500), have to be done annually. In-place recycling is used very widely, different applications for soft asphalt (REMO) and hot mix asphalt (REM), width of treatment 1-1,5 m (URA-REMO/URA-REM) or lane 3-4 m (REMO/REM). Thin overlays = REM+, MPKJ (earlier MPK, TASK). Bonded wearing courses=

Novachip, only 1 contractor offers. Q11-Q12; some answers: http://alk.tiehallinto.fi/julkaisut/pdf2/4000731-v-uusiopaallysteiden_kaytto.pdf
it would be nice if Pavement Preservation would fit in nice rectangular boxes & you could build an EASY button to answer all of these questions
We currently use one set of deterioration curves for "built" roads, and another set for "unbuilt" roads. As time and data allow, we would like to develop additional deterioration curves.
Cold asphalt mixture is also applied in some areas, especially in cold season.
In Finland we have now requirements for the thickness of asphalt layer so that less raveling will happen.
1.Hermansson A. Laboratory and field testing on rate of frost heave versus heat extraction(2004).Cold regions science and technology:137-151. 2.Simonsen E, and Isacsson U. Thaw weakening of pavement structures in cold regions(1999). Cold regions science and technology: 135-151. 3.Park D.Y. Effect of temperature and loading time on the stiffness properties of HMAC in Flexible Pavements(2000).Doctoral thesis of Michigan State University.

Statistic	Value
Total Responses	13