
Preventive Maintenance

CHAPTER 4

The word “maintenance,” when used in relation to highways and bridges, refers to a wide assortment of activities that range from routine pothole filling to fairly substantial overlays. Our emphasis in this chapter is on maintenance activities that are preventive in nature, that is, activities that are performed to prevent or delay the occurrence of urgent and/or extensive maintenance problems. In this chapter, we asked:

- **What does research show about the effectiveness and cost-effectiveness of preventive maintenance?**
- **To what extent does the Minnesota Department of Transportation (Mn/DOT) perform adequate preventive maintenance on state trunk highways and trunk highway bridges?**

To answer these questions, we reviewed studies on preventive maintenance; surveyed individuals in the seven outstate Mn/DOT district offices and the Metropolitan Division who are familiar with the maintenance of Minnesota’s state trunk highway system; spoke to managers at the district offices, Metropolitan Division, and central office; and obtained data from Mn/DOT’s bridge and pavement management systems on preventive maintenance activities performed on the trunk highway system.

DEFINITION

Preventive maintenance of highways and bridges includes activities that are performed while a structure is still in fairly good condition. For our study, we adopted a definition of “preventive maintenance” from a study by the Transportation Research Board and used by a Mn/DOT “pathbuilding team” that looked at the issues of preventive maintenance and preservation in 1994.¹ Preventive maintenance is:

¹ Mn/DOT created three pathbuilding teams to further the department’s understanding of how “business practices could be applied to the public sector to further its strategic management process.” Minnesota Department of Transportation, *Pathbuilding Projects: Final Report* (St. Paul, December 1994), 6. The three team topics were: finance, preventive maintenance/preservation, and marketing.

a program strategy intended to arrest light deterioration, retard progressive failures, and reduce the need for routine maintenance and service activities. Preventive maintenance is generally cyclic in nature. It is planned maintenance. Preventive maintenance activities do not significantly improve the load-carrying capacity of pavements, shoulders, or structures but extend the useful life and improve the level of service.²

Much pavement preventive maintenance is performed to keep moisture out of the pavement subbase. Moisture in the subbase can weaken the support the subbase provides to the pavement, leading to cracking and, during freeze-thaw cycles, potholes. Water under concrete slabs can contribute to faulting at the joints between the slabs.³ Pavement preventive maintenance can also reduce the quantity of incompressible objects in pavement joints and cracks, which can obstruct the natural movement of the pavement in response to temperature changes. We describe the pavement preventive maintenance activities on which we focused in Figures 4.1 and 4.2. Some of the bituminous and bituminous-over-concrete activities, and all of the concrete activities, on which we focused are usually performed by contractors, as opposed to Mn/DOT maintenance crews.

Figure 4.1: Preventive Maintenance Activities for Bituminous and Bituminous-over-concrete Pavement

crack fill--Crack filling consists of placing a material such as an asphalt emulsion¹ into a crack. The material reduces water infiltration and reinforces the adjacent pavement. This procedure is generally used to maintain older cracks.

crack seal--Crack sealing (or rout and seal) involves routing a crack into a special configuration and filling it with a material such as rubberized asphalt. The material prevents incompressible objects and moisture from entering the crack.

fog seal--Fog sealing is the application of an asphalt emulsion. Fog seals coat the road surface and may fill small cracks. These seals are more commonly used on low-volume roads and shoulders because surface friction might be reduced after application.

sand seal--Sand sealing involves applying asphalt emulsion to a road surface, followed by a sand cover. The sand provides some friction and the seal may provide some protection from moisture.

slurry seal--Slurry sealing consists of applying a mixture of fine aggregate,² emulsion, water, and mineral filler to the road surface. A slurry seal may be applied to the full width of the road, or used to repair cracks and other minor defects. When applied full-width, slurry seals seal the pavement surface and may improve minor defects and friction.

micro-surface--Micro-surfacing is basically a special type of slurry seal that uses higher quality materials and a special binder. Micro-surfacing has been used to fill wheel ruts and improve friction, among other things. This treatment can be used on high-volume roads.

² Louis G. O'Brien for the Transportation Research Board, *National Cooperative Highway Research Program, Synthesis of Highway Practice Report 153: Evolution and Benefits of Preventive Maintenance Strategies* (Washington, D.C.: National Research Council, December 1989), 7.

³ Two adjacent concrete slabs form a joint. Ideally, the slabs are level. A fault occurs when one of the slabs of concrete is elevated so that the adjacent slabs are no longer level.

Figure 4.1: Preventive Maintenance Activities for Bituminous and Bituminous-over-concrete Pavement, continued

single- and multiple-application chip seal--Chip sealing involves applying an asphalt emulsion followed by an aggregate cover. Chip seals may waterproof the road surface, seal low-severity cracks, and improve surface friction. Use of chip seals is usually restricted to low-volume roads.

asphalt overlay (2.0" or less)--Asphalt overlaying consists of applying a surface of hot-mix asphalt. Asphalt overlays improve the smoothness of a road and the friction of the pavement surface. Thin overlays typically do not add to the load carrying capacity of the pavement.

¹An asphalt emulsion is a mixture of asphalt cement, water, and an emulsifying agent.

²Aggregate is a mixture of mineral particles such as sand, gravel, or rocks.

Figure 4.2: Preventive Maintenance Activities for Concrete Pavement

reseal joints--Joints in concrete pavements are resealed to prevent moisture and incompressible objects such as sand from entering the joint. Water penetrating the cracks may cause fine material below the concrete slab to wash out, reducing the pavement support, and incompressibles may increase the likelihood of pavement blowups during freeze-thaw cycles.

repair spalled¹ joints--Repairing spalled joints before the spalling becomes too severe improves the smoothness of the ride of the road and may prevent further deterioration, which would require more extensive and expensive repairs.

install edge drains--Edge drains provide a system for water that reaches a pavement's base layer to drain out of the base materials. Edge drains are important when the pavement has a poorly draining subgrade, such as clay or silt.

retrofit load transfer--Retrofit load transfer involves doweling (or fastening) concrete slabs together with a metal bar to help reduce the impact of traffic on the concrete slabs. Retrofit load transfer may help reduce faulting² and the ejecting of fine materials under the concrete slabs up through joints and cracks. The latter weakens the pavement support.

grind concrete--Grinding improves the smoothness of the ride on concrete pavements that have experienced faulting at cracks or joints. It may also slow down or prevent the ride from becoming rough again and reduce the impact of traffic.

¹Ideally, the edge of a concrete panel is a relatively sharp 90-degree angle. Two adjacent panels form a joint. A spalled joint is one in which the sharp edges of the concrete panels forming the joint have worn away, leaving a rougher and wider opening to the joint.

²Two adjacent concrete panels form a joint. Ideally, the panels are level and traveling from one to the other is barely noticeable. A fault occurs when one of the panels of concrete is elevated due to water problems and traffic, so that the adjacent panels are no longer level.

On bridges, most of the preventive maintenance activities on which we focused are designed to reduce the exposure of bridge components to water and corrosive agents, such as de-icing chemicals, or to reduce the effects of stress on the bridge, such as that caused by the expansion and contraction of components in response to temperature changes. We describe the bridge preventive maintenance activities on which we focused in Figure 4.3. Most of the bridge preventive maintenance activities on which we focused are usually performed by Mn/DOT bridge maintenance crews.

Figure 4.3: Preventive Maintenance Activities for Bridges

crack seal on concrete decks--Crack sealing of bridge decks prevents water and corrosive materials from reaching the reinforcing steel in the deck.

lubricate expansion bearings--Expansion bearings are lubricated to maintain their ability to move. Bearings that cannot move in response to expansion of bridge components may cause stress on other components of the bridge.

flush winter residue--Salt, sand, debris, and corrosive materials are flushed from bridge decks and other surfaces (such as bridge seats) to prevent the concrete from cracking and scaling and steel components from corroding.

reinstall strip neoprene glands--A strip neoprene gland is a flexible material placed in expansion joints to prevent water and debris from reaching components below the bridge deck. The glands can pull out of the joints or tear.

clean and reseal joints--Joints that are not sealed with neoprene glands are filled with some other material, such as cork or felt, that is covered with a sealer. These joints are hard to maintain, and the seal does not last long. The joints need to be cleaned and resealed to prevent corrosive materials from leaking onto components below the deck.

spot paint--A protective coat of paint prevents corrosion of steel elements. Spot painting may extend the life of the paint coat.

install relief joints in concrete approaches--Relief joints in concrete approaches to bridges relieve the pressure on bridge components caused by expanding concrete. The pressure may cause damage to bridge components.

correct approach panel settlement¹--Correcting approach panel settlement improves the smoothness of the ride and safety and reduces the impact of traffic on the bridge.

place drain extensions on floor drains--Drain extensions carry water away from the supporting structures below the bridge deck.

Note: These activities were taken from the list of preventive maintenance activities in Mn/ DOT's Bridge Maintenance Manual. The manual includes activities not included above.

¹Approach panel settlement occurs when the approach panel to the bridge settles so that it is on a lower level than the bridge.

RESEARCH

Most of the studies we reviewed found pavement preventive maintenance activities to be effective if they were applied to pavements at the right time using proper materials and application procedures. Preventive maintenance cannot be expected to extend the life or improve the service of a pavement or bridge that was poorly constructed or that has already deteriorated. The appropriateness of an activity for a specific highway or bridge may depend on traffic volume and climate, among other things.

An Indiana study looked at the trade off between two maintenance activities: sealing cracks and joints (preventive maintenance) and patching (demand

maintenance). The authors found that “if more cracks are sealed before winter, less patching is required after winter, primarily because of fewer potholes.”⁴

In 1994, the Transportation Research Board surveyed state, local, and Canadian transportation agencies about their experiences with pavement preventive maintenance.⁵ Table 4.1 shows that state transportation agencies generally observed increases in pavement life that they attributed to preventive maintenance activities.⁶ Some of the variation in experience may be due to differences in design, materials, or work quality, and it is possible that some of the roads were not good candidates for preventive maintenance.

Table 4.1: States’ Reported Increase in Pavement Life Attributed to Preventive Maintenance Activities

<u>Surface and Activity</u>	<u>Most Common Response</u>	<u>Range of Responses</u>	<u>States Responding¹</u>
BITUMINOUS			
Crack filling ²	2-4 years	Less than 2 to 7-8 years	29
Single-application chip seal	5-6 years	2-4 to 7-8 years	26
Multiple-application chip seal	5-6 years	2-4 to 9-10 years	12
Slurry seal	2-4 years	2-4 to 5-6 years	7
Micro-surface	5-6 years	2-4 to 7-8 years	11
Thin hot-mix asphalt overlay (1.25 inches or less)	7-8 years	2-4 to 9-10 years	23
CONCRETE			
Joint spall repair	5-6 years	2-4 to 15 years	21
Joint sealer replacement	5-6 years	2-4 to 9-10 years	18

Source: Donald N. Geoffroy, for the Transportation Research Board, *National Cooperative Highway Research Program Synthesis of Highway Practice 223: Cost-Effective Preventive Pavement Maintenance* (Washington, D.C.: National Academy Press, 1996), 54-60.

¹This is the number of states responding for each activity. It does not include states that responded “unknown” or N/A.

²The survey asked about crack filling with or without routing.

The Federal Highway Administration (FHWA) is studying the effectiveness of pavement preventive maintenance on “test sections” of highways. The test sections are located throughout the United States and Canada and were constructed using the same crew, materials, and design to control some of the variables that can affect preventive maintenance performance. In the early 1990s, the FHWA completed subjective visual field evaluations of 87 sections. The evaluators concluded that the sections that received preventive maintenance were generally performing better than those that had not, and the preventive

⁴ Essam A. Sharaf and Kumares C. Sinha, “Energy Savings from Increased Preventive Maintenance on Indiana Highways,” *Transportation Research Record 1102: Highway Maintenance Planning* (Washington, D.C.: National Research Council, 1986), 28.

⁵ Donald N. Geoffroy, for the Transportation Research Board, *National Cooperative Highway Research Program Synthesis of Highway Practice 223: Cost-Effective Preventive Pavement Maintenance* (Washington, D.C.: National Academy Press, 1996). Forty-five states, four Canadian provinces, and eleven local agencies responded.

⁶ The increases in pavement life were primarily estimates based on observational experience of agency staff.

Many studies have found preventive maintenance to be effective.

maintenance was more effective when performed on pavements that were in better condition.⁷

The American Association of State Highway and Transportation Officials, in its 1987 Manual for Bridge Maintenance, states, "Most problems can be prevented or minimized by timely preventive maintenance for bridges."⁸ Some activities mentioned in this manual include cleaning the deck, joints, substructure caps, and bearings; spot painting; and maintaining joint seals. In the mid-1980s, several researchers interviewed bridge maintenance engineers who identified the following effective practices: flushing bridge seats; cleaning, painting, and lubricating bearings; and flushing and providing good drainage for the deck.⁹ Neither of these publications evaluated the activities.

Several studies have concluded that the benefits of pavement preventive maintenance exceed the costs.¹⁰ However, the measures of costs and benefits have varied across studies. Benefits may include lower repair and rehabilitation costs over the life of the pavement or structure and improved ride quality and safety. Costs generally include the cost of labor and materials and may include user delay costs.

A study on sand sealing and chip sealing in Indiana estimated that agency and vehicle operating costs would be lower over the life of a pavement if sealing were performed at the appropriate times.¹¹ Researchers from the Ministry of Transportation in Ontario concluded that crack sealing in bituminous pavements, when done at the right time, was cost-effective when total agency and some user costs were considered.¹² A third study concluded that "undertaking [maintenance and rehabilitation] actions on pavement in 'good' condition may cost only \$1.00 for every \$4.00 that would be necessary for appropriate [maintenance and rehabilitation] if the pavement were left to deteriorate into poor condition."¹³

7 Raza Hassan, *Summary Report: 1993 Field Evaluations of SPS-3 and SPS-4 Test Sites*, Publication No. FHWA-SA-94-078 (Washington, D.C.: Federal Highway Administration, October 1994). Additional studies supporting the effectiveness of pavement preventive maintenance are cited below because they also support the cost-effectiveness of these treatments.

8 American Association of State Highway and Transportation Officials *AASHTO Manual for Bridge Maintenance* (Washington, D.C., 1987), 3.

9 J.M. Kruegler, G.M. Briggs, C.C. McMullen, and G.A. Earnhart *Cost-Effective Bridge Maintenance Strategies, Volume II: Guidelines and Recommendations*, Report No. FHWA/RD-86/110 (McLean, Virginia: Federal Highway Administration, June 1986).

10 The distinction between effectiveness and cost-effectiveness is important. The effectiveness of a treatment refers to its ability to achieve a desired result. Cost-effectiveness also considers whether the benefits of a treatment exceed the cost. It is possible that a treatment could be effective in extending pavement life (i.e., be effective), but cost more than the additional years of life are worth.

11 Abdullah I. Al-Mansour and Kumares C. Sinha, "Economic Analysis of Effectiveness of Pavement Preventive Maintenance" *Transportation Research Record 1442: Maintenance of the Highway Infrastructure* (Washington, D.C.: National Academy Press, 1994), 31-37.

12 Joseph Ponniah and Gerhard Kennepohl, "Crack Sealing in Flexible Pavements: A Life-Cycle Cost Analysis," Transportation Research Board 74th Annual Meeting, Paper #950763 (January 22-28, 1995).

13 Essam A. Sharaf, Mohamed Y. Shahin, and Kumares C. Sinha, "Analysis of the Effect of Deferring Pavement Maintenance," *Transportation Research Record 1205: Pavement Maintenance 1988* (Washington, D.C.: National Research Council, 1988), 29-35.

However, not all studies support the effectiveness (and therefore the cost-effectiveness) of preventive maintenance of pavements. For example, researchers at the Wisconsin Department of Transportation are studying sealing joints in concrete pavements and have questioned its effectiveness.¹⁴ Some studies showed mixed results on the effectiveness of micro-surfacing. With four years of data, one study showed micro-surfacing to be more resistant to re-rutting than a 1.5 inch asphalt overlay, but less resistant to cracking.¹⁵ In another study, poorly performing test sections were usually attributable to problems during application of the micro-surfacing materials or inadequate treatment design. The researcher concluded that the experience of the contractors and quality control throughout the micro-surfacing process were very important to successful use of micro-surfacing.¹⁶

Mn/DOT is currently participating in a study of the cost-effectiveness of pavement preventive maintenance. A description of the study says the study will look at existing data on maintenance obtained from state and local agencies and supplement it with new data obtained from test sections constructed primarily on the state trunk highway system. The study will focus on preventive maintenance treatments for bituminous pavements, such as slurry sealing, crack filling, and micro-surfacing. Both agency and user costs will be considered in the calculation of cost-effectiveness.

Mn/DOT is responsible for preventive maintenance on the State Trunk Highway System.

Mn/DOT PRACTICES

Mn/DOT performs preventive maintenance on state trunk highways and bridges, or arranges for the preventive maintenance to be performed by contractors. The decisions about which activities to use on which highways and bridges, and how much money to spend on preventive maintenance versus other activities, are made by the Mn/DOT districts and the Metropolitan Division.

Mn/DOT provided us with data on the amount of preventive maintenance performed on bituminous, bituminous-over-concrete, and concrete pavements between 1986 and 1995, as recorded in its pavement management system.¹⁷ As Table 4.2 shows, contractors sealed cracks on about 1,700 miles of bituminous

¹⁴ Stephen F. Shober, "The Great Unsealing: A Perspective on PCC Joint Sealing," Wisconsin Department of Transportation, (unpublished). We discussed this study with an engineer at Mn/DOT who suggested the current findings of the study are applicable to pavements on certain types of bases for which drainage is not much of a problem. Other test sections were too new to draw a conclusion.

¹⁵ C.M. "Swede" Pederson and William J. Schuller, "Micro Surfacing with Natural Latex Modified Asphalt Emulsion: A Field Evaluation" (Oklahoma Department of Transportation, August 1987).

¹⁶ Dean A. Maurer, "Ralumac Latex-Modified Bituminous Emulsion Mixtures: A Summary of Experience in Pennsylvania," Research Project 82-22 (Pennsylvania Department of Transportation, April 1987).

¹⁷ According to Mn/DOT, the pavement management system records all contract work and some asphalt overlays performed by Mn/DOT crews. Overlays that are at least a half-mile long and are performed by Mn/DOT crews are included. Other work performed by Mn/DOT crews is not reflected in these figures.

Table 4.2: Miles of Selected Activities on the State Trunk Highway System, 1986-95

Activity	Miles of Activity ¹			Annual Average
	1986-90	1991-95	Total	
BITUMINOUS/BITUMINOUS-OVER-CONCRETE				
Crack Seal	273	1,392	1,665	167
Chip Seal	547	668	1,215	122
Asphalt Overlay (2" or less)	1,320	1,383	2,703	270
CONCRETE				
Reseal Joints	441	33	474	47
Repair Spalled Joints ²	651	527	1,178	118

Source: Minnesota Department of Transportation.

¹Miles of work include all contract work and some asphalt overlays performed by Mn/DOT maintenance crews. Overlays that are at least a half-mile long and performed by Mn/DOT crews are included.

²Includes partial-depth repair and more extensive full-depth repair.

and bituminous-over-concrete highways and chip sealed just over 1,200 miles in this ten-year period. Contractors or Mn/DOT crews also applied thin asphalt overlays (less than or equal to two inches) on almost 2,700 miles of bituminous and bituminous-over-concrete highways. According to Mn/DOT records, about 22 percent more miles were chip sealed and 3 percent more miles were overlaid with a thin asphalt layer in the second five-year period (1991-95) than in the first five years. The records also showed that cracks were sealed in five times as many miles in 1991-95 than in 1986-90.

On concrete pavement, contractors resealed joints in over 450 miles of highway and repaired spalled joints in over 1,100 miles of highway. Mn/DOT records show that spalled joints were repaired on about 20 percent fewer miles in the second five-year period (1991-95) than in the previous five-year period. Records also showed that joints were resealed on about 92 percent fewer miles in the second five-year period, relative to the period 1986-90. Over the ten-year period, the number of concrete roadway miles on the state trunk highway system declined about 16 percent.

We asked Mn/DOT to use its pavement management system to see if there were pavements that were in a condition such that preventive maintenance might be appropriate. The pavement management system analyzes information on condition ratings, levels of surface defects, age, and average daily traffic on the state trunk highways. The pavement management system recommends one or more possible actions based on the pavement information. The recommendations

We asked Mn/DOT managers around the state about their use of preventive maintenance.

range from “do nothing” to “reconstruct.”¹⁸ The results of the analysis show that about 65 percent of state trunk highway miles *might* benefit from preventive maintenance. This does not mean that two-thirds of the highway miles need immediate preventive maintenance. However, these miles are in good enough condition for preventive maintenance to be considered.

Though the pavement management system can supply information on the level of activity taking place and the number of miles that might benefit from preventive maintenance, it does not give an indication of whether this level of activity is appropriate. To help us evaluate whether Mn/DOT is doing enough preventive maintenance, we sent questionnaires to the District Engineers and the Metropolitan Division Engineer. One questionnaire asked about preventive maintenance of bituminous and bituminous-over-concrete pavement, one asked about preventive maintenance of concrete pavement, and one asked about preventive maintenance of bridges. The specific activities we asked about are described in Figures 4.1, 4.2, and 4.3.

We asked the engineers to distribute the surveys to those individuals who could best respond for the districts’ maintenance areas.¹⁹ For each questionnaire, we received 12 responses from individuals in supervisory and management positions representing all parts of the state. In most cases, we also spoke with the people who returned the questionnaires for clarification and further explanation of answers.

Some responses we received represent an entire district, while others represent a maintenance area within a district. Figure 4.4 shows the organizational units that responded. Maintenance areas and districts do not represent equal miles of bituminous pavement or concrete pavement, or equal numbers of bridges, so we did not weight responses in any way.²⁰ We think the responses we received convey what the people familiar with preventive maintenance think about its use in the areas where they work.

¹⁸ At our request, the decision criteria used by the pavement management system to assess the pavements that might benefit from preventive maintenance are different from the criteria used in the current system. The criteria used were developed by a Mn/DOT pathbuilding team on preventive maintenance based on the members’ years of experience and engineering expertise. These criteria, which will be incorporated into the pavement management system, contain more options for pavements in relatively good condition, for which preventive maintenance might be appropriate. The current criteria focus more on pavements in relatively worse condition.

¹⁹ Four of the outstate Mn/DOT districts (Districts 1, 3, 6, and 7) are divided into two maintenance areas. Districts 2 and 4 formerly had separate maintenance areas, but no longer do. District 8 has maintenance sub-area, but not separate maintenance areas. We asked for responses for the separate maintenance areas because we thought practices might differ among them. However, for each of the three questionnaires, three districts responded with only one questionnaire for the whole district. The Metropolitan Division Engineer was asked to forward the questionnaires to the people who could respond for the entire metropolitan area.

²⁰ In analysis not reflected in this report, we counted each single district response and the Metropolitan Division response twice, as if each maintenance area or sub-area had responded. The results did not change the general conclusions we draw in this chapter, though specific relationships sometimes changed.

Managers from all regions of the state responded to our questionnaire.

Figure 4.4: Responses to the Preventive Maintenance Questionnaires

Pavement Questionnaires

District 1
 District 2
 Maintenance Area 3A
 Maintenance Area 3B
 Maintenance Area 4A
 Maintenance Area 4B
 Maintenance Area 6A
 Maintenance Area 6B
 Maintenance Area 7A
 Maintenance Area 7B
 District 8
 Metropolitan Division

Bridge Questionnaire

District 1
 Maintenance Area 2A
 Maintenance Area 2B
 Maintenance Area 3A
 Maintenance Area 3B
 District 4
 Maintenance Area 6A
 Maintenance Area 6B
 Maintenance Area 7A
 Maintenance Area 7B
 District 8
 Metropolitan Division

Bituminous and Bituminous-over-concrete Pavement

Bituminous and bituminous-over-concrete pavements together comprise about 80 percent of Minnesota's state trunk highway roadway miles. Bituminous pavements include both originally constructed bituminous highways and bituminous highways that have been overlaid with a bituminous layer. Bituminous-over-concrete highways, as their label would suggest, are highways that were originally constructed as concrete but have since been overlaid with a bituminous layer. The preventive maintenance activities on which we focused for these two types of pavements are the same and, in the remainder of this section, we use "bituminous" to refer to both.

The questionnaire we sent the district offices and the Metropolitan Division asking about preventive maintenance activities for bituminous pavement focused on the nine activities described in Figure 4.1. Of the nine activities we asked about, five had been used in most respondents' areas since January 1990. The five activities that had been performed in most areas include crack filling, crack sealing, fog sealing, single-application chip sealing, and asphalt overlaying.²¹

Managers gave various reasons for why sand sealing, slurry sealing, multiple-application chip sealing, and micro-surfacing had not been used. For example, lack of pavements requiring the treatment, ineffectiveness of the treatment, and lack of cost-effectiveness in the respondent's area were cited as reasons why sand sealing and multiple-application chip sealing were not used. For slurry sealing, managers cited the newness of the procedure and either a lack of opportunity to try it or a desire to see performance in other areas before using it. A lack of Mn/DOT equipment or private contractors who perform micro-surfacing and the

²¹ The question read: "Since January 1990, have Mn/DOT crews or contractors performed this activity on any of your maintenance area's bituminous or BOC pavements? 1.) Yes 2.) No 3.) Don't know."

newness of the procedure were cited by respondents as reasons why more of this activity does not occur.²²

Table 4.3 shows that:

- **Mn/DOT managers responding to our questionnaire said their areas performed the right amount of some preventive maintenance activities, but too little of other activities.**

For example, almost all managers said that too little crack filling was performed in their areas, and half thought too little crack sealing was performed. Some people thought the right amount of almost all activities was performed in their areas, while others thought they did not perform the right amount of any

Table 4.3: Questionnaire Responses on Adequacy of Pavement Preventive Maintenance

Mn/DOT managers thought they did the right amount of some activities, but too little of others.

Activity	We do "too little"	We do the "right amount"	No Response
BITUMINOUS/BITUMINOUS-OVER-CONCRETE PAVEMENT			
Crack fill	11	1	0
Asphalt overlay (2" or less)	7	5	0
Crack seal	6	5	1
Fog seal	6	6	0
Slurry seal	6	3	3
Micro-surface	6	1	5
Sand seal	4	6	2
Single-application chip seal	4	7	1
Multiple-application chip seal	4	6	2
CONCRETE PAVEMENT			
Repair spalled joints	6	5	1
Reseal joints	5	7	0
Grind concrete	4	8	0
Install edge drains	2	10	0
Retrofit load transfer	1	4	7

Note: The question read: "In your professional opinion, how adequate is your maintenance area's use of this treatment? (Please consider only the need for the activity, not budget or other constraints.)"

Source: Program Evaluation Division questionnaire sent to Minnesota Department of Transportation district offices and the Metropolitan Division, 1996.

²² The question read: "For each activity that has not been performed in your maintenance area since January 1990, which reason best explains why? 1.) It is not effective in our maintenance area 2.) It is not cost-effective in our maintenance area. 3.) We have not had any pavements in the condition for which this treatment should be used. 4.) Other 5.) Don't know?"

Resource constraints limit the amount of preventive maintenance performed.

activity.²³ However, most managers' responses were somewhere between these two extremes. The wide range of opinion may in part be explained by different levels of preventive maintenance that respondents feel are "adequate" and by different interpretations of what "adequate" means.

About half the time, Mn/DOT managers indicated that resource constraints, either financial or personnel, at least partly explained why some preventive maintenance activities are used too little. However, for some individual activities, other reasons were cited more frequently. For example, traffic volumes were cited most often as the reason more chip sealing is not done.²⁴

Concrete Pavement

We also asked the Mn/DOT district offices and the Metropolitan Division about their use of and experience with preventive maintenance activities for concrete pavement. The activities are described in Figure 4.2. Resealing joints, repairing spalled joints, installing edge drains, and grinding concrete had been performed in most of the respondents' areas since January 1990. Retrofit load transfer had been used in five areas.²⁵

Table 4.3 shows how managers felt about the adequacy of their use of concrete preventive maintenance activities.²⁶ Compared to their use of bituminous preventive maintenance,

- **Mn/DOT managers generally were more satisfied with their use of concrete pavement preventive maintenance, but some were concerned that Mn/DOT may not be attending to concrete joints early enough to prevent more costly problems from developing.**

23 The number of activities respondents thought were being performed too little in their areas ranged from one to nine. The question read: "In your professional opinion, how adequate is your maintenance area's use of this treatment? (Please consider only the need for the activity, not budget or other constraints.) 1.) We perform too little of this. 2.) We perform the right amount of this. 3.) We perform too much of this." Some respondents did not provide an opinion on the adequacy of use for all activities. In these cases, the individuals indicated the activity had not been used in their area since January 1990 and they felt they did not have enough experience with the activity to form an opinion. Originally, 25 items were unanswered. Based on follow-up calls we recoded twelve of the missing responses. Two were recoded as "too little." Ten were recoded as "the right amount."

24 The question read: "For each activity for which you indicated your maintenance area performs too little," why doesn't your maintenance area use this treatment more? (Indicate all that apply.) 1.) We do not have adequate funds to perform this activity on all applicable roads. 2.) It is hard to justify performing this activity on roads in relatively good condition when other roads are in worse condition. 3.) Maintenance workers are performing other maintenance activities. 4.) Maintenance workers are working in other areas (e.g., performing construction inspections). 5.) This activity is not a maintenance area, district, and/or agency priority. 6.) Traffic volumes prevent more use of this treatment. 7.) Other 8.) Don't know."

25 The question read: "Since January 1990, have Mn/DOT crews or contractors performed this activity on any of your maintenance area's concrete pavements? 1.) Yes 2.) No 3.) Don't know."

26 The question read: "In your professional opinion, how adequate is your maintenance area's use of this treatment? (Please consider only the need for the activity, not budget or other constraints.) 1.) We perform too little of this. 2.) We perform the right amount of this. 3.) We perform too much of this."

**Trunk
highways
might benefit
from earlier
and more
frequent
concrete joint
work.**

Five managers said they performed too little joint resealing and six said they performed too little repairing of spalled joints. According to activity data maintained in Mn/DOT's pavement management system, contractors repaired spalled joints on about 80 percent as many miles and resealed joints on about 8 percent as many miles in the five years 1991-95 as in the previous five-year period.²⁷ In a national study, most of the states that provided information reported first replacing joint sealer and first repairing spalled joints in the first ten years of pavement life, while Minnesota reported a pavement age of 12 years at first treatment.²⁸ Responses to our questionnaire suggest the pavement might even be older than 12 years, on average, when this work is first done. This is not necessarily evidence that too little of these activities is being performed; other factors can affect the use of these treatments. For example, one respondent told us that his area has a large quantity of failed concrete pavements because of the quality of aggregate used during construction, and resealing joints would not help. Another told us, "Our concrete roads are getting old enough that we have done repairs once or twice already. The next fix would be bigger."

We asked why too little of some preventive maintenance activities is performed. The most common reason given by Mn/DOT managers was inadequate funds. The second most frequently cited reason for too little work being performed was the difficulty in justifying work on roads in relatively good condition when other roads are in worse condition.²⁹

Bridges

In the bridge questionnaire, we asked Mn/DOT about the preventive maintenance activities described in Figure 4.3. It is not surprising that all but one of the activities (extending floor drains) had been performed in most respondents' areas since January 1990 because all of the activities we asked about are recommended in Mn/DOT's Bridge Maintenance Manual.³⁰

27 According to Mn/DOT, its pavement management system records work done under contract and some asphalt overlays performed by Mn/DOT's maintenance crews. If any joint spall repair or resealing of joints was performed by Mn/DOT crews, it would not be captured in these figures. According to questionnaire respondents, both types of activities are usually performed under contract, though one respondent indicated joint resealing is performed by Mn/DOT crews and under contract.

28 Geoffroy, *Cost-Effective Preventive Pavement Maintenance*, 54-55 (Appendix D). Fifteen of 21 states repaired spalled joints in the first ten years and 17 of 22 states replaced joint sealer in the first ten years.

29 The question read: "For each activity for which you indicated your maintenance area performs too little," why doesn't your maintenance area use this treatment more? (Indicate all that apply.) 1.) We do not have adequate funds to perform this activity on all applicable roads. 2.) It is hard to justify performing this activity on roads in relatively good condition when other roads are in worse condition. 3.) Maintenance workers are performing other maintenance activities. 4.) Maintenance workers are working in other areas (e.g., performing construction inspections). 5.) This activity is not a maintenance area, district, and/or agency priority. 6.) Traffic volumes prevent more use of this treatment. 7.) Other 8.) Don't know."

30 Minnesota Department of Transportation, Office of Bridges and Structures *Bridge Maintenance Manual* (St. Paul, February 27, 1996), Section 5-399.100. Half of the respondents reported that none of their bridges needed floor drain extensions since January 1990.

Table 4.4 shows that:

- **Mn/DOT managers responding to our questionnaire said their areas performed the right amount of some bridge preventive maintenance activities, but too little of other activities.**

Table 4.4: Questionnaire Responses on Adequacy of Bridge Preventive Maintenance

Activity	We do "too little"	We do the "right amount"	No Response
Spot paint	11	1	0
Clean/reseal deck joints	9	3	0
Lubricate expansion bearings	8	4	0
Correct approach panel settlement	7	5	0
Crack seal concrete decks	5	7	0
Reinstall strip neoprene glands	5	7	0
Install relief joints in concrete approaches	5	7	0
Flush winter residue	3	9	0
Place drain extensions on floor drains	1	10	1

Note: The question read: "In your professional opinion, how adequate is your maintenance area's use of this treatment? (Please consider only the need for the activity, not budget or other constraints.)"

Source: Program Evaluation Division questionnaire sent to Minnesota Department of Transportation district offices and the Metropolitan Division, 1996.

For example, most managers felt their areas were doing too little spot painting of bridges.³¹ Bridge maintenance people mentioned the difficulty of doing spot painting cost-effectively because of the environmental and safety regulations involved with removing lead-based paint.

Nine of the twelve respondents felt their areas were doing too little cleaning and resealing of bridge deck joints. According to one Mn/DOT publication, "One of the most serious bridge maintenance problems is leaky expansion joints."³² Ideally, joints should not leak. If joints with poured joint sealer are leaking, the joints should be cleaned and resealed. If joints with strip neoprene glands are leaking, the glands should be repaired or replaced. Table 4.5 shows the percent of bridges with leaking joints recorded in the bridge maintenance management system as of September 1996.³³ About 70 percent of bridges with poured joint sealer had at least one leaking joint. Only 9 percent of bridges with neoprene

³¹ The question read: "In your professional opinion, how adequate is your maintenance area's use of this treatment? (Please consider only the need for the activity, not budget or other constraints.) 1.) We perform too little of this. 2.) We perform the right amount of this. 3.) We perform too much of this."

³² Minnesota Department of Transportation, *Transportation Research 1995 Annual Report* (St. Paul), 49.

³³ The condition information we received contains the most recent inspection information as of September 1996. The actual inspection dates for the bridges vary.

Table 4.5: Bridge Expansion Joint Condition

Type of Expansion Joint	Number of Bridges	Bridges with Leaking Joints	Percent of Bridges with Leaking Joints
Poured joint sealer	258	186	72%
Neoprene gland	1,982	176	9
Other ¹	167	142	85
Total with joints	2,407	504	21

Note: Only the condition of the expansion joint in the worst condition is noted. Not every joint in a bridge with one leaking joint is necessarily leaking.

Source: Program Evaluation Division analysis of data from the Minnesota Department of Transportation's Bridge Maintenance Management System, September 1996.

¹Includes three bridges that did not have "type of device" information but did have condition information.

glands had leaking joints; most of the state trunk highway bridges have this type of expansion joint.³⁴

Most of the managers answering our questionnaire thought they were doing the right amount of bridge flushing. Flushing winter residue from bridges is one preventive maintenance activity for which Mn/DOT has a recommended frequency against which we could compare actual performance. It is important to flush bridges to prevent concrete from cracking and scaling and steel components from corroding. By analyzing data maintained in Mn/DOT's bridge maintenance management system, we found that:

- **Mn/DOT flushes bridges less frequently than the once-a-year frequency recommended in the Mn/DOT Bridge Maintenance Manual.**

Table 4.6 shows that, based on two years of data from the bridge maintenance management system, bridges are being flushed, on average, once every three years. Some bridges were flushed more than once during the two years, so some bridges probably have a once-a-year cycle, while others are flushed even less frequently than the once-every-three-years average we calculated.

We called a few of the managers who responded to our questionnaire for possible explanations of why the bridge flushing activity was below recommended levels. We learned that the bridge maintenance management system does not contain information about all of the bridge flushing activity that occurs. For example, Duluth has the longest cycle between flushing in Table 4.6, but this may partly reflect the fact that highway maintenance workers do some of that district's bridge flushing, and the flushing done by these workers is not recorded in the bridge maintenance management system. Managers also told us that it is less important to flush certain bridges each year, such as bridges that are not treated with a lot of

³⁴ One respondent who initially indicated that his area does the right amount of reinstallation of strip neoprene glands said the latest inspections revealed a lot of the glands in his area were pulling out of the joints and needed to be replaced. Two respondents who said their replacement of neoprene glands is adequate indicated that they patch the glands a lot and if they had more money, they would do more replacement of the glands.

Mn/DOT needs to flush debris from bridges more frequently.

Table 4.6: Flushing Activity on State Trunk Highway Bridges, Calendar Years 1994-95

District	Bridges ¹	Number of Flushes ²	Cycle in Years ³
1 - Duluth	333	62	10.7
2 - Bemidji	129	74	3.5
3 - Brainerd	221	324	1.4
4 - Detroit Lakes	147	102	2.9
6 - Rochester	392	329	2.4
7 - Mankato	221	200	2.2
8 - Willmar	137	222	1.2
Metropolitan Division	944	318	5.9
Total	2,524	1,631	3.1

Source: Program Evaluation Division analysis of data from the Minnesota Department of Transportation's Bridge Maintenance Management System.

¹The number of bridges is the number we estimate were open in both 1994 and 1995.

²The number of flushes includes flushing of the entire bridge or any component of the bridge, as recorded in the Minnesota Department of Transportation's Bridge Maintenance Management System. Deck flushing by non-bridge crews is not reflected. Some bridges were flushed more than once in the two-year period.

³The "cycle" refers to the years between flushes based on the activity for the two years 1994-1995.

de-icing chemicals. This may explain why most managers felt their bridge flushing activity was adequate even though it does not meet the once-a-year standard.³⁵

We explored bridge flushing in the metropolitan area more closely because over a third of the bridges for which we had information are in the metropolitan area and the use of de-icing chemicals might be more intense because of traffic volumes. In the Metropolitan Division, the Metro West bridge maintenance superintendent said he emphasizes flushing bridges inside the Interstate 494-694 loop because the high volume of traffic leads to more chemicals being used during the winter. The Metro East superintendent said he thought his crews probably flushed more bridges outside the loop, except for a few structures inside the loop over the Mississippi River that have a lot of exposed steel. As Table 4.7 shows, Metro West does do more flushing of bridges inside the loop, though the frequency still does not meet the recommended standard. Metro East did little bridge flushing, especially inside the loop. The six recorded flushings inside the Interstate 494-694 loop on the east side occurred on three bridges, two over the Mississippi River and one over Interstate 35E.

We asked Mn/DOT managers why some preventive maintenance activities on bridges were not performed enough, and their most common response was that maintenance workers were performing other maintenance activities. Since most bridge preventive maintenance work is performed by Mn/DOT crews, it is not surprising that this explanation would be more common for bridges than for

³⁵ Two people said that, in their opinions, some bridges with strip neoprene glands should be flushed more than once a year.

Bridges are seldom flushed in the East Metro area and Northeastern Minnesota.

Table 4.7: Bridge Flushing Inside the Twin Cities Interstate 494-694 Loop, Calendar Years 1994-95

	Metro <u>West</u>	Metro <u>East</u>	Total <u>Metro</u>
Bridges within the 494-694 loop ¹	409	267	676
Flushes within the 494-694 loop ²	250	6	256
Cycle within the loop ³	3.3	89.0	5.3
Bridges outside the 494-694 loop	125	143	268
Flushes outside the 494-694 loop	48	14	62
Cycle outside the loop	5.2	20.4	8.6
Total bridges in area	534	410	944
Total flushes in area	298	20	318
Overall cycle	3.6	41.0	5.9

Source: Program Evaluation Division analysis of data from the Minnesota Department of Transportation's Bridge Maintenance Management System.

¹The number of bridges is the number we estimate were open in both 1994 and 1995.

²The number of flushes includes flushing of the entire bridge or any component of the bridge as recorded in the Minnesota Department of Transportation's Bridge Maintenance Management System. Deck flushing by non-bridge crews is not reflected. Some bridges were flushed more than once in the two-year period.

³The "cycle" refers to the years between flushes based on the activity for the two years 1994-1995.

In almost half the cases, Mn/DOT managers thought they performed too little preventive maintenance.

pavements. This reason was followed by inadequacy of funds and difficulty in justifying work on bridges in relatively good condition when others are in worse condition.³⁶

Additional Analysis

Mn/DOT managers responding to our questionnaire gave a mixed report on the adequacy of preventive maintenance of Minnesota's state trunk highway system. In our questionnaire, there were 127 instances in which managers indicated they were doing the right amount of a particular preventive maintenance activity, compared with 126 instances in which they said they did too little. But we were surprised to find that:

- **In about half the cases where Mn/DOT managers reported performing the right amount of a preventive maintenance activity, they also indicated they would spend additional money on the activity if funds were available.**

³⁶ The question read: "For each activity for which you indicated your maintenance area performs too little," why doesn't your maintenance area use this treatment more? (Indicate all that apply.) 1.) We do not have adequate funds to perform this activity on all applicable bridges. 2.) It is hard to justify performing this activity on bridges in relatively good condition when other bridges are in worse condition. 3.) Maintenance workers are performing other maintenance activities. 4.) Maintenance workers are working in other areas (e.g., performing construction inspections). 5.) This activity is not a maintenance area, district, and/or agency priority. 6.) Traffic volumes prevent more use of this treatment. 7.) Other 8.) Don't know."

Respondents frequently explained that they were maintaining the system at a certain level and were doing a reasonable amount of preventive maintenance given their resource constraints, but they thought there were additional opportunities to use preventive maintenance if funds were available.³⁷

Table 4.8 shows that most Mn/DOT managers responding to our questionnaire thought that most of the activities we asked about are cost-effective. In addition, Mn/DOT's 1996 performance report says that not performing preventive maintenance causes increased costs in later years, which increases the cost of state

**Generally,
Mn/DOT
managers
believe
preventive
maintenance is
cost-effective.**

Table 4.8: Mn/DOT Managers' Opinions on Cost-Effectiveness of Preventive Maintenance

Activity	In your professional opinion, is this activity cost-effective in your maintenance area, or would it be if it were used? (n=12)		
	Yes	No	Don't know
BITUMINOUS/BOC			
Crack fill	83%	0%	17%
Crack seal	83	0	17
Asphalt overlay (2" or less) ¹	92	0	0
Fog seal	75	0	25
Sand seal ¹	42	0	50
Slurry seal	25	8	67
Micro-surface	33	0	67
Single-application chip seal ¹	67	0	25
Multiple-application chip seal ¹	17	0	75
CONCRETE			
Reseal joints	100%	0%	0%
Retrofit load transfer	25	0	75
Repair spalled joints	83	17	0
Grind concrete ²	67	17	17
Install edge drains	92	0	8
BRIDGES			
Crack seal	92%	0%	8%
Lubricate expansion bearings	92	0	8
Flush winter residue	100	0	0
Reinstall strip neoprene glands	100	0	0
Spot paint ²	83	8	8
Clean/reseal bridge deck joints	100	0	0
Install relief joints in concrete approaches	75	0	25
Correct approach panel settlement	92	0	8
Place drain extensions on floor drains	83	0	17

Source: Program Evaluation Division questionnaire sent to Minnesota Department of Transportation district offices and the Metropolitan Division, 1996.

¹Percents do not total 100 percent because one respondent did not answer.

²Percents do not total 100 percent because of rounding.

³⁷ The question read: "If you had additional funds at your disposal, would you spend any on this particular activity? 1.) Yes 2.) No 3.) Don't know?"

Preventive maintenance tends to be a lower priority than more immediate problems.

road operations per lane mile.³⁸ However, when determining how to use their budgets, Mn/DOT districts and the Metropolitan Division try to address safety and congestion problems, in addition to considering ways to prevent later maintenance problems. Also, sometimes work needs to be done on highways and bridges in poor shape to maintain them until they can be programmed for reconstruction. Finally, the amount of preventive maintenance work performed sometimes depends on the amount of money districts spend on other maintenance activities. For example, a harsh winter might deplete maintenance budgets because of Mn/DOT's snow and ice removal responsibilities.

In sum, Mn/DOT managers generally believe that preventive maintenance is cost-effective and would do more of it, but preventive maintenance tends to be a lower priority than more pressing problems. Perhaps this reflects the fact that the negative impacts of deferring preventive maintenance are not noticeable in the short-term. Managers often feel compelled to respond to more immediate public concerns, such as a pothole-filled or bumpy highway, before they invest in strategies that might prevent some of these problems from developing.

RECOMMENDATIONS

Data provided in Chapter 2 show that bridge and pavement quality have stayed relatively constant over the past 10 years, indicating that Mn/DOT is keeping Minnesota's state trunk highway system in the shape to which Minnesotans have become accustomed. However, we question whether Mn/DOT is maintaining highways and bridges in the most cost-effective manner.

- **In our opinion, Mn/DOT should take a more strategic approach to preventive maintenance on the state's trunk highway system.**

A more strategic approach to preventive maintenance might include:

Mn/DOT should take a more strategic approach to preventive maintenance.

- (1) developing maintenance strategies that suggest when specific activities should be performed in the life of a pavement or structure;
- (2) continuously evaluating the cost-effectiveness of preventive maintenance techniques, treatments, and strategies;
- (3) setting aside funds for specific types of preventive maintenance; and
- (4) at least initially, making centralized decisions about the most cost-effective preventive maintenance projects to pursue.

We think Mn/DOT should consider developing formal preventive maintenance strategies. A 1994 survey of state, local, and Canadian transportation agencies asked the agencies about their pavement preventive maintenance strategies. A

³⁸ Minnesota Department of Transportation, *1996 Performance Report* (St. Paul, December 1996), 110.

**Mn/DOT
should evaluate
any new
strategies it
develops.**

preventive maintenance strategy was defined as, “A plan for applying a series of preventive maintenance treatments over the life of the pavement. It is an organized, systematic process to select and budget preventive maintenance activities over the life of the pavement so as to minimize life cycle costs.”³⁹ Twenty-two states (including Minnesota) of 45 states responding to the survey said they did not have formal preventive maintenance strategies for pavements. States with strategies generally reported observing an increase in time before pavement rehabilitation was required, a decrease in time and money spent on demand maintenance activities, and an improvement in pavement smoothness.

According to a report published by the Federal Highway Administration, “A single preventive maintenance treatment will improve the quality of the pavement surface and extend the pavement life. However, the true benefits of pavement preventive maintenance are realized when there is a consistent schedule for performing the preventive maintenance.”⁴⁰ The report also said that preventive maintenance is defined less by the activities that are used than by *when* those activities are employed. “To be cost-effective,” the authors wrote, “pavement preventive maintenance treatments should be applied before most engineers, or project decision makers would normally consider their use.”⁴¹ If Mn/DOT developed strategies and made a long-term commitment to evaluate them, it could confirm that its strategies are cost-effective, or learn that it needs to modify them.

Mn/DOT already has invested in pavement and bridge management systems that could help develop and evaluate preventive maintenance strategies. Mn/DOT developed its pavement management system (PMS) in the 1980s. In 1994, a Mn/DOT “pathbuilding team” on preventive maintenance recognized the possibility of using the PMS to suggest and evaluate preventive maintenance activities.⁴² Prior to that time, the system had been used to suggest activities for highways in relatively poor condition. The pathbuilding team developed decision criteria that suggest activities for pavements in relatively good condition. Those criteria are being included in a new version of the PMS. Mn/DOT’s bridge management system (PONTIS) already has the ability to identify preventive maintenance activities that would be appropriate at particular times.⁴³

³⁹ Geoffroy, *Cost-Effective Preventive Pavement Maintenance*, 42 (Appendix B).

⁴⁰ John P. Zaniewksi and Michael S. Mamlouk, *Preventive Maintenance Effectiveness-Preventive Maintenance Treatments: Participant’s Handbook* (Washington, D.C.: Federal Highway Administration, February 1996), 39.

⁴¹ Zaniewksi and Mamlouk, *Preventive Maintenance Effectiveness-Preventive Maintenance Treatments*, 5.

⁴² Minnesota Department of Transportation, *Pathbuilding Projects: Final Report* (St. Paul, December 1994), 23-30.

⁴³ Two issues affecting the usefulness of both the bridge and pavement management systems for evaluating preventive maintenance are (1) the thoroughness and reliability of data and (2) calculation of costs and benefits. As mentioned previously, we found some bridge flushing was not recorded in the bridge maintenance management system, and the pavement management system includes only contract work and some asphalt overlays done by Mn/DOT crews. Overlays that are at least a half-mile long and are performed by Mn/DOT crews are included. Regarding calculation of costs and benefits, the benefits of preventive maintenance would probably be reflected by a change in highways’ and bridges’ rates of deterioration. For bridges, the benefits might extend beyond the component directly being maintained. Also, neither system measures costs beyond agency costs of materials and labor.

Preventive maintenance is too important to handle inconsistently.

We suggest the department consider setting aside funds for preventive maintenance and, at least initially, exercise some central control over selecting the projects. We concluded in the previous section that the amount of preventive maintenance that Mn/DOT performs may depend on how much Mn/DOT spends on more obvious and immediate demands. If Mn/DOT set aside funds for preventive maintenance, which is currently funded by both the construction and operations budgets, perhaps the districts and the Metropolitan Division would be less likely to defer preventive maintenance when other transportation concerns arise. As investment in preventive maintenance is increased, over time it would be expected that the amount of rehabilitation work and demand maintenance activities, such as patching potholes, would decrease somewhat. Initial central office oversight in selecting projects might make Mn/DOT better able to evaluate the cost-effectiveness of preventive maintenance treatments and strategies by establishing and using uniform criteria to determine the types and timing of preventive maintenance to be used.

For example, comments from Mn/DOT managers suggest that a more systematic approach to maintaining concrete joints that are new and/or in good condition might be beneficial. If earlier and more frequent attention to concrete joints were part of a formal maintenance strategy for concrete pavements, and if funds were set aside to perform the scheduled activities, the result might be a reduction in overall spending by catching problems before major concrete repairs are required. Using the pavement management system to evaluate the strategy for concrete preventive maintenance would inform the department if the strategy it adopted was having the anticipated effects.

If preventive maintenance is as cost-effective as Mn/DOT managers and the research literature suggest, it is too important for Mn/DOT to deal with inconsistently. We think Mn/DOT should develop a statewide strategy and carefully evaluate its results over time.