OFFICE OF THE LEGISLATIVE AUDITOR
STATE OF MINNESOTA

EVALUATION REPORT

MnDOT Selection of Pavement Surface for Road Rehabilitation

MARCH 2014

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O L A **OFFICE OF THE LEGISLATIVE AUDITOR**
STATE OF MINNESOTA • James Nobles, Legislative Auditor

March 2014

Members of the Legislative Audit Commission:

The Minnesota Department of Transportation (MnDOT) has a process to determine whether its road rehabilitation projects will be constructed with bituminous or concrete pavements. Minnesota's pavement industries have questioned that process.

In April 2013, the Legislative Audit Commission directed the Office of the Legislative Auditor to evaluate MnDOT's process for selecting pavement type in road rehabilitation projects. We found that MnDOT follows many but not all practices recommended in national literature for selecting pavement type.

We make several recommendations to improve MnDOT's process. For example, we recommend that MnDOT estimate certain user costs, such as the costs of time delays to travelers in work zones, over the life cycle of pavement alternatives. We also suggest that MnDOT develop a way to more formally consider other factors, such as local government preferences, that affect pavement decisions. Beyond improvements to the process, we recommend that the Legislature repeal certain statutory language that has produced misleading life-cycle cost analyses in some cases.

Our evaluation was conducted by Jody Hauer (evaluation manager) and David Greenwood-Sanchez. We were assisted by American Engineering Testing, Inc., a consulting firm we retained for help with technical matters. MnDOT cooperated fully with our evaluation.

Sincerely,

James Nobles
Legislative Auditor

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Table of Contents

		Page
	SUMMARY	**ix**
	INTRODUCTION	**1**
1.	**BACKGROUND**	**3**
	Types of Pavement Surface	3
	Road Rehabilitation	5
	Minnesota Department of Transportation	6
	Pavement Industries	14
2.	**RECOMMENDED PRACTICES FOR SELECTING TYPE OF PAVEMENT**	**17**
	Practices for Selecting Pavement Type	18
	Develop a Policy for Selecting Pavement	18
	Identify Potential Pavement Alternatives	21
3.	**LIFE-CYCLE COST ANALYSES**	**31**
	Defining Life-Cycle Cost Analyses	31
	Recommended Practices	34
	Evaluate Pavement Alternatives	53
4.	**ALTERNATE BIDDING**	**59**
	Defining Alternate Bidding	59
	MnDOT'S Use of Alternate Bidding	59
	Recommended Practices	62
5.	**OTHER ISSUES**	**73**
	Statutory Requirement	73
	MnDOT's Concrete Pavement Designs	76
	LIST OF RECOMMENDATIONS	**79**
	AGENCY RESPONSE	**81**
	RECENT PROGRAM EVALUATIONS	**85**

List of Exhibits

Page

1. BACKGROUND

1.1 Pavement Structure Layers 4
1.2 Pavement Projects by Category, Fiscal Years 2009-2013 6
1.3 Examples of Common Pavement Rehabilitation and Maintenance 7
1.4 Minnesota Department of Transportation Districts 8
1.5 Trunk Highway Lane Miles by Minnesota Department of Transportation District, 2013 9
1.6 Overview of Minnesota Department of Transportation's Process for Developing Road Rehabilitation Projects 10
1.7 Key Decision Points for Selecting Pavement Type 11
1.8 Total Pavement Spending and Road Rehabilitation Spending in Contracts by District, Fiscal Year 2013 13
1.9 Contracted Spending on Road Rehabilitation by Pavement Type, Fiscal Years 2009-2013 14

2. RECOMMENDED PRACTICES FOR SELECTING TYPE OF PAVEMENT

2.1 Recommended Practices for Selecting Pavement Type for Road Rehabilitation 19
2.2 Factors to Consider in Developing Policies on Pavement Selection 20
2.3 Minnesota Department of Transportation Measures of Pavement Condition 23
2.4 Examples of Pavement Distress Measured by the Minnesota Department of Transportation 25

3. LIFE-CYCLE COST ANALYSES

3.1 Legal and Policy Requirements for Minnesota Department of Transportation (MnDOT) Life-Cycle Cost Analyses of Road Rehabilitation Projects 32
3.2 Compliance with Requirement for a Life-Cycle Cost Analysis 33
3.3 Hypothetical Life-Cycle Cost Analyses 35
3.4 Rehabilitation and Maintenance Scheduling 36
3.5 Recommended Practices for Life-Cycle Cost Analyses 37
3.6 Minnesota Department of Transportation Discount Rates for Life-Cycle Cost Analyses, 2007-2014 39
3.7 Changes in Pavement Materials' Prices as Measured from a 1987 Base of 100, 1987-2012 41
3.8 Agency Costs Recommended for Use in Life-Cycle Cost Analyses 45
3.9 Noneconomic Factors to Consider when Evaluating Pavement Alternatives 55

Page

4. ALTERNATE BIDDING
4.1 Alternate Bidding Projects by Minnesota Department of Transportation District, Fiscal Years 2009-2013 60
4.2 Recommended Practices for an Alternate Bidding Process 63

5. OTHER ISSUES
5.1 Age of Pavement for Maintenance Treatments, by Concrete Design Life 75

Summary

The Minnesota Department of Transportation (MnDOT) meets many recommended practices for selecting pavement type in road rehabilitation projects, but it needs to improve analyses of life-cycle costs and change its "alternate bidding" process.

Major Findings:

- The Minnesota Department of Transportation (MnDOT) meets many but not all recommended practices for selecting pavement for road rehabilitation projects. (pp. 18, 34, 63)
- State law requires comparing pavement alternatives of "equal design life," but national literature does not recommend it. Neither law nor policy defines the term, and interpretations differ. (pp. 73-75)
- MnDOT's identification of feasible pavement alternatives is incomplete. Costs and timing of similar maintenance in life-cycle cost analyses differed by MnDOT district; the basis for data districts used was not always shown. (pp. 21, 46, 47)
- When comparing pavement alternatives, MnDOT does not evaluate "user costs," although doing so is recommended. Further, MnDOT assesses only some of the recommended noneconomic factors and does not have a process to evaluate all relevant economic and noneconomic factors. (pp. 51, 56)
- MnDOT's approach for computing life-cycle costs does not account for the uncertainty of inputs such as pavement costs. (p. 52)
- MnDOT is considering using material-specific inflation rates in calculating pavement materials' costs, but the case for doing so is weak, and forecasting long-term inflation is unsupported in economics literature. (p. 43)
- MnDOT's use of alternate bidding has had limited impact on bid prices and industry competition. MnDOT cost estimates and schedules of maintenance do not reflect local conditions. (pp. 61-62)

Key Recommendations:

- The Legislature should repeal the requirement on equal design lives in life-cycle cost analyses. (p. 75)
- MnDOT should identify a full range of pavement alternatives. It should require districts to update cost estimates, as needed, in their life-cycle cost analyses and justify their estimates of costs and timing of rehabilitation and maintenance. (pp. 24, 46, 48)
- MnDOT should change its alternate bidding process. Its cost estimates should better reflect districts' market conditions; its rehabilitation schedules should reflect road conditions. (pp. 65-66, 72)
- MnDOT should quantify certain user costs and supplemental costs and also account for the uncertainty of inputs in life-cycle cost analyses. (pp. 51, 53)
- MnDOT should develop a process for weighing both economic and noneconomic factors before selecting pavement type. (p. 57)
- MnDOT should avoid using material-specific inflation rates to calculate life-cycle costs. (p. 44)

Report Summary

In general, road pavements are either bituminous (also called asphalt) or concrete. They need rehabilitation when they crack or exhibit other stresses but can still support traffic. The Minnesota Department of Transportation (MnDOT) is responsible for developing and administering state transportation programs, including those for rehabilitating roads on the state trunk highway system. It has eight district offices that are chiefly responsible for identifying road problems and assessing ways to fix them.

Most of MnDOT's pavement projects are road rehabilitation projects. Between fiscal years 2009 and 2013, 85 percent of pavement projects were rehabilitation; the rest were new construction or reconstruction. Of 388 rehabilitation projects during this period, 88 percent were bituminous, 10 percent were concrete, and 2 percent were both pavement types. In fiscal year 2013, total MnDOT contracts for road rehabilitation summed $365.5 million.

Minnesota's two paving industries have voiced concerns about MnDOT's process and policies for selecting the type of pavement used in rehabilitation projects. In this evaluation, we compared MnDOT's procedures to those recommended by national experts. We found that MnDOT follows many recommended practices but not all of them.

Some cost estimates in MnDOT life-cycle cost analyses are outdated, or a basis for the data is unknown.

An important component of selecting pavement type is conducting life-cycle cost analyses. Such analyses require calculating costs of rehabilitation and maintenance over the entire lifetime of pavement alternatives, converting future costs to present-day values, and identifying the low-cost pavement.

"Agency costs" are a basic component of life-cycle cost analyses. These are the costs of pavement alternatives' initial and future rehabilitation and maintenance over a specified period (often 35 years). The costs are to be based on historical bid data and reflect market prices at the time of construction.

MnDOT bases its costs on historical data. However, in a sample of 40 projects, 12 (30 percent) had costs that were more than a year old at the time the project was let for bidding; 2 of those were more than three years old. When cost estimates are not timely, MnDOT should update them.

In life-cycle cost analyses, districts enter costs of an initial rehabilitation based on their own experience. Some also enter their own costs of future rehabilitation and maintenance, and the years in which that work is expected to occur. The analyses do not consistently make clear the basis for determining initial and future costs and timing of the work. MnDOT should require districts to justify their cost estimates and timing of rehabilitation and maintenance in life-cycle cost analyses.

National literature on life-cycle cost analyses does not recommend comparing pavement alternatives of "equal design life," but Minnesota law requires it.

Minnesota law requires comparing pavement alternatives of "equal design life," even though doing so is not recommended.

Statutes require MnDOT to compare life-cycle costs for pavement alternatives having "equal design lives." However, neither law nor

MnDOT policy defines the phrase. Interpretations of the phrase differ among MnDOT's materials engineers. National literature on life-cycle cost analyses does not recommend equal design lives. Until 2014, MnDOT standards did not include thin concrete designs, making it difficult to identify alternatives of equal design life.

For life-cycle cost analyses, MnDOT policy requires that at least two pavement alternatives of opposite materials have equal design lives. In analyses containing more than two pavement alternatives, a district can comply with the policy even when it selects an alternative that does not have a design life equal to the others. In a sample of 19 projects, districts in 8 cases (42 percent) selected a low-cost alternative with a design life different from other pavement alternatives.

The requirement for equal design lives is unnecessary if districts compare pavement alternatives over an equal number of years and calculate the pavement's remaining service life at the end of those years. Further, in early 2014, MnDOT issued design guidelines for thinner concrete overlays than in the past. Districts may now use such designs when circumstances warrant them. The Legislature should repeal from law the requirement for equal design lives in life-cycle cost analyses.

MnDOT data on feasible pavement alternatives are incomplete.

To select appropriate pavement type, it is important to first identify potential pavement alternatives. MnDOT's data for doing so are incomplete. MnDOT should identify a full range of feasible pavement alternatives for road rehabilitation.

MnDOT does not estimate user costs of pavement alternatives.

In evaluating pavement alternatives, MnDOT does not account for costs of drivers' time delays or vehicle operating costs.

"User costs" are costs incurred by drivers when traveling through work zones of rehabilitation projects. They include costs of drivers' time delays and vehicle operating costs. National literature recommends estimating user costs when they can be estimated reasonably and when they differ among the pavement alternatives under consideration. However, MnDOT's policy prohibits districts from including user costs in life-cycle cost analyses; nor are such costs evaluated in other documents. Some districts informally consider user costs, such as when a pavement alternative would require 100-mile detours. MnDOT should determine the conditions and rehabilitation strategies associated with high user costs and require districts to estimate the costs when they are likely to vary widely among pavement alternatives.

MnDOT does not consider all factors affecting pavement alternatives or formally evaluate economic and noneconomic factors.

National literature recommends formally evaluating economic and noneconomic factors that affect pavement alternatives. MnDOT districts identify pavement alternatives for road problems and are required to analyze the alternatives' economic factors. But MnDOT does not require districts to analyze some recommended noneconomic factors, especially nontechnical ones, such as resource conservation or municipalities' preferences on pavement type. Further, MnDOT does not use a formal decision-making tool to objectively weigh all economic and noneconomic aspects of pavement alternatives. MnDOT should require districts to evaluate

MnDOT's economic analysis of "alternate bidding," where both pavement industries bid on a project to determine the pavement type, showed the process had little economic advantage over traditional projects.

relevant noneconomic factors. It should also develop a process for weighing all factors pertaining to the pavement alternatives.

MnDOT does not account for uncertainty in the data used in life-cycle cost analyses.

Computations in life-cycle cost analyses can be based on a single, fixed value, such as an average cost for a bituminous overlay based on costs from past projects. A recommended alternative is to acknowledge the uncertainty behind those values and use statistical measures to identify the likelihood that a specific estimate will actually occur. MnDOT's process for computing life-cycle costs does not account for the uncertainty of inputs, such as pavement costs. MnDOT should study the feasibility of estimating life-cycle costs while accounting for the uncertainty of values for specific inputs.

MnDOT uses statewide averages to calculate life-cycle costs for projects using "alternate bidding."

In alternate bidding, both industries bid on a road project, and the pavement type is determined in the winning bid, not by MnDOT. The intent is to increase competition and get optimal prices on road projects.

For alternate bidding, national experts recommend using historical bid data to estimate costs of rehabilitation and maintenance over a pavement's life cycle. MnDOT does this, but it uses statewide average costs in lieu of a district's costs. Further, MnDOT uses a centrally developed schedule of rehabilitation and maintenance activities. MnDOT should continue to estimate costs centrally but modify them when such estimates do not reflect market prices in the district. MnDOT should use the central schedule of rehabilitation unless it does not reflect local road conditions and needs.

MnDOT's use of alternate bidding has had limited impact on bid prices and pavement industry competition.

Agencies should periodically review their alternate bidding process. MnDOT's economic analysis showed alternate bidding had little economic advantage over traditional projects. MnDOT should change alternate bidding, such as by targeting it to more suitable projects.

The case for using material-specific inflation rates is weak.

For life-cycle cost analyses, national literature recommends that agencies use cost estimates that are presented in "real" dollars—removing the effects of inflation. MnDOT's practices do this.

Some people argue that recent high costs of bituminous should be reflected in estimates of future costs in life-cycle cost analyses. The U.S. Office of Management and Budget recommends using real dollars instead of predicting future inflation, unless there is reliable evidence supporting different patterns of future costs. Research on forecasting inflation for oil prices shows that estimates of "no change in price" are superior to methods predicting specific oil price changes, except for in the very short-term—far shorter than the 35-year horizon of life-cycle cost analyses. The uneven nature of long-term bituminous prices makes predicting inflation difficult. MnDOT has considered calculating life-cycle costs with material-specific inflation rates but should avoid such calculations.

Introduction

When roads on Minnesota's state trunk highway network need rehabilitation due to cracks or other signs of distress, the Minnesota Department of Transportation (MnDOT) is responsible for planning and overseeing the work. One key decision will be whether to use bituminous or concrete to rehabilitate the pavement.

Legislators and others have raised concerns regarding the process MnDOT uses to choose between bituminous or concrete pavements. In April 2013, the Legislative Audit Commission directed the Office of the Legislative Auditor to evaluate that process. We addressed the following questions:

- **What methods does MnDOT use to determine the preferred pavement type for road rehabilitation projects?**

- **How reasonable are MnDOT's methods for selecting pavement type? To what extent have MnDOT districts around the state followed those methods in their road projects?**

- **To what extent do MnDOT's methods reflect recommended practices?**

To answer these questions, we examined state laws and MnDOT technical memoranda, manuals, and other reports related to selecting pavement. We reviewed background documents on the properties of bituminous and concrete and various methods used to rehabilitate and maintain paved roads.

To identify recommended practices associated with selecting pavement type, we conducted an extensive literature review. We sought relevant documents from major transportation organizations, such as the Transportation Research Board, as well as from universities that have conducted academic research on the topic. After synthesizing the information, we identified a set of recommended practices we deemed necessary for a systematic process of choosing pavements.

We conducted interviews with MnDOT personnel and others. This included numerous interviews with staff in MnDOT's Office of Materials and Road Research, which has responsibility for guiding pavement selection. We also interviewed representatives of the paving industries' trade associations, including the Concrete Paving Association of Minnesota, the Minnesota Asphalt Pavement Association, and the Associated General Contractors of Minnesota.

To understand MnDOT district perspectives, we conducted structured interviews with materials engineers and soils engineers in MnDOT's eight districts. Some questions covered the districts' processes and procedures; others were specific to individual road projects. We made site visits to four of the districts and conducted interviews via video conference with the others.

For information on MnDOT road projects, we selected a sample of rehabilitation projects to study in depth. Using data from MnDOT on 484 pavement projects let for construction from July 1, 2008, through June 30, 2013, we isolated 408 rehabilitation projects. We stratified the projects by MnDOT's eight districts for a sample that represented the proportion of all rehabilitation projects in each district. The sample of 52 projects is too small to be representative of all projects in the state, but it yielded important information at the individual project level. For each project in the sample, we collected pertinent documents, including life-cycle cost analyses, from MnDOT databases. We examined the documents for background information on the projects and for components required by law and MnDOT policy, such as on how to complete life-cycle cost analyses.

We analyzed data from a variety of MnDOT sources. Our analyses included data on road miles and condition, pavement types, and rehabilitation costs. They also included data on the costs and timing of pavement alternatives, which was obtained from individual road project documents.

Because of the many technical aspects of pavement design, we hired American Engineering Testing, Inc., based in St. Paul, to provide us engineering expertise. The consultant assisted us with our technical questions, provided additional analyses, and accompanied us during interviews with MnDOT district personnel. However, the views in this report are the responsibility of the Office of the Legislative Auditor and should not be interpreted as necessarily reflecting the views of American Engineering Testing, Inc.

Chapter 1 of this report provides background information on pavement type, road rehabilitation projects, MnDOT, and the paving industries. In Chapter 2, we outline five model practices needed for selecting pavement and explain two of the practices. Chapter 3 focuses on two more of the model practices, which pertain to analyzing life-cycle costs and comparing pavement alternatives. The final of the five model practices relates to alternate bidding, which Chapter 4 defines and explains. Chapter 5 describes other timely issues related to the process of selecting pavement type for road rehabilitation in Minnesota.

1 Background

All roads eventually need work to maintain an acceptable level of performance. Preventive maintenance may be used when roads are still in relatively good condition. When pavement can still support traffic but begins to exhibit cracking or other distresses that affect its performance, rehabilitation work is required. If the pavement is damaged beyond repair, then a more costly road reconstruction is needed.

The Minnesota Department of Transportation (MnDOT) is responsible for developing and administering state transportation planning and programs, including rehabilitation of state roads. Roads maintained by counties, cities, and townships were not included in this evaluation.

This chapter introduces the principal concepts and participants involved with road rehabilitation in Minnesota. We start by discussing the types of pavement and road rehabilitation on Minnesota's trunk highway system. We describe MnDOT roles in road rehabilitation and the general process MnDOT uses to develop rehabilitation projects. Finally, we provide information on the size of Minnesota's road network, the costs of these roads, and the pavement industries that bid on contracts for road work.

TYPES OF PAVEMENT SURFACE

Generally speaking, a pavement surface is either bituminous or concrete.

Generally speaking, there are two types of pavement surface: bituminous (also called asphalt) and concrete. In both cases, the pavement surface is the top layer of a multilayered structure, as Exhibit 1.1 illustrates. The layers have materials that are designed to depths of up to five feet (or more in some cases) below the pavement surface.

The surface layer needs to withstand traffic loads and environmental wear to provide a long lasting, smooth, riding surface for vehicles while providing sufficient friction to prevent skidding. Surface layers consist of "aggregate"—a general term for mineral substances like gravel, sand, and finer particles—and a "binder" to hold the aggregate together. The two main types of binders are asphalt and Portland cement.

Bituminous

Pavements constructed with an asphalt binder are known as "bituminous" pavements because of the bitumen content of asphalt.[1] They are also known as "flexible" pavements because they give slightly under the weight of traffic. A flexible pavement relies on its lower layers of materials for support, but the

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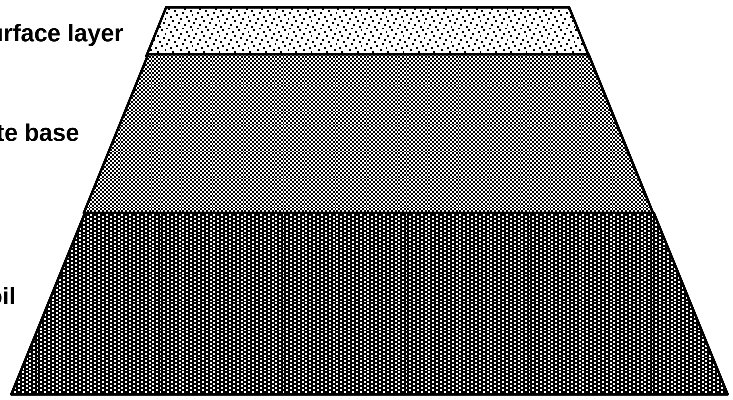
[1] Bitumen is a naturally occurring byproduct of decomposed organic material and is composed of hydrocarbons; it is also obtained as residue from refining petroleum.

Pavement surface is part of a multilayered structure.

Exhibit 1.1: Pavement Structure Layers



NOTE: This exhibit depicts a simplistic pavement structure and is not intended to represent a specific pavement design used by the Minnesota Department of Transportation.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Transportation, "DRAFT Chapter 7 Pavement Type Selection," *MnDOT Pavement Design Manual* (St. Paul, 2013), 27, 33.

highest load-bearing material is on top. There are different types of bituminous pavements. An example of a common one is "hot mix asphalt" pavement, which consists of specific proportions of well-graded aggregate and asphalt binder and is heated at a bituminous plant before being hauled to a construction site. "Cold mix" pavements are another example. They use asphalt emulsion (asphalt, water, and an agent for blending the liquid), require little or no heating of the materials, and are typically produced at a construction site. Reclaimed asphalt products can be recycled for future bituminous pavements.

Concrete

The second type of binder is Portland cement—so named for its similarity in color to the limestone quarried from the Isle of Portland in England. Pavements constructed with it are known as "Portland cement concrete" (or simply, concrete) pavements. Concrete pavements are also known as "rigid" pavements because they do not flex as much under pressure as asphalt pavements do. Different types of concrete pavements use joints or reinforcing steel to accommodate pavement expansion and contraction. One example of a common type is "jointed plain concrete pavement," which uses concrete slabs with transverse joints between the slabs to absorb pavement expansion and contraction.[2]

[2] Transverse joints are spaces between concrete sections; the joints are located at right angles to the pavement's center line.

ROAD REHABILITATION

Roads need rehabilitation when they exhibit distress but can still support traffic.

MnDOT separates road pavement projects into three main types: (1) reconstruction and new construction, (2) rehabilitation, and (3) preventive maintenance. Department procedures and design standards differ by each type of project.

MnDOT carries out *reconstruction* work on roads that are damaged beyond repair, do not provide the necessary safety and capacity to meet travel demand, and need to be completely rebuilt. MnDOT performs *rehabilitation* on roads that exhibit distress but can still support traffic. The choice between reconstruction or rehabilitation depends on the degree of degradation of the road, safety and geometric (lane width and number of lanes) considerations, and the costs of alternate fixes. MnDOT performs *preventive maintenance* on roads still in good structural condition to extend the life of the pavement surface.[3] This report focuses primarily on road *rehabilitation* projects.

Rehabilitation accounts for the vast majority of MnDOT's road projects. Between fiscal years 2009 and 2013, 85 percent of all pavement projects (388 of 459) were rehabilitation. Exhibit 1.2 shows the number of projects by program category for new construction, reconstruction, and the various types of rehabilitation including: reconditioning, resurfacing, and road repair.[4]

Types of Rehabilitation and Maintenance

Road rehabilitation accounted for 85 percent of MnDOT's pavement projects between fiscal years 2009 and 2013.

Rehabilitation is usually done to improve the structural capacity of a roadway. Maintenance, on the other hand, is usually done to extend pavement life or improve ride quality. Exhibit 1.3 defines some of the common rehabilitation and maintenance for each type of pavement.

Rehabilitation activity often involves an "overlay," which is a new layer of concrete or asphalt on top of existing pavement. Overlays may be applied to existing pavements of either concrete or asphalt. For example, asphalt overlays can be applied to existing asphalt pavement—where the existing pavement may be "milled" before the new pavement is applied—and to existing concrete pavement, which can be broken into pieces and compacted to form a new base for the asphalt.

Concrete can be applied to existing concrete or bituminous pavements. When applied over existing bituminous, it is called "whitetopping." Concrete overlays can be either "bonded" or "unbonded" to the existing pavement. Bonding the

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[3] Preventive maintenance involves surface treatments or, in some cases, patches or applications of the same pavement type as the existing pavement; it does not involve alternate pavement types.

[4] Data on the projects are from MnDOT's Program and Project Management System. Reconditioning is correcting road conditions that are critically deficient, such as widening lanes and correcting drainage, without major changes to a cross section of the road. Resurfacing is restoring the roadway surface and/or the shoulders. Repair is minor road preservation needed to achieve the normal life expectancy of a roadway. MnDOT uses the different categories primarily to make funding distinctions. Specific techniques within the categories range from those that increase the structural capacity of the road to those that are simple treatments of the surface.

Exhibit 1.2: Pavement Projects by Category, Fiscal Years 2009-2013

Category	2009	2010	2011	2012	2013	Total	Percentage of Total Projects
New Construction	5	5	6	6	6	28	6%
Reconstruction	8	7	4	13	11	43	9
Reconditioning	14	12	12	14	12	64	14
Resurfacing	53	43	53	65	74	288	63
Repair	6	11	7	9	3	36	8
Total	86	78	82	107	106	459	100%

NOTES: Rehabilitation projects include reconditioning, resurfacing, and repair projects. We did not include exclusively preventive maintenance projects in this table because they do not involve the selection of a new pavement surface. Of 484 pavement projects let during this time period, 25 were excluded because they had no reported contract value, no reported mileage, or a reported mileage of zero.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Transportation Program and Project Management System data.

Rehabilitation typically improves the structural capacity of a road; by contrast, maintenance usually helps prolong pavement life.

concrete to the existing pavement provides structural support in that the bond and existing pavement perform as one structure. However, the existing pavement needs to be in fair to good condition to achieve a successful bond. If the existing pavement is in relatively poor condition, an "unbonded" overlay can be constructed by using a thin layer of asphalt or special synthetic fabric to separate the new pavement from the existing pavement. The separation between existing and new pavement prevents distress in the existing pavement from harming the overlay.

Maintenance activities are typically done to prolong the life of the pavement by slowing weathering, sealing cracks, and providing a smoother surface. For bituminous pavements for instance, "chip seals" are a sprayed application of asphalt covered by a layer of uniformly sized aggregate; it is intended to protect the pavement from deterioration due to sun and rain. For concrete pavements, maintenance consists of various activities including sealing cracks, patching, fixing joints, and grinding for smoothness. As one example, "partial depth repairs" means removing fragmented concrete and replacing it with high-strength concrete.

MINNESOTA DEPARTMENT OF TRANSPORTATION

MnDOT has a central office and eight districts around Minnesota, each of which plays a primary role in road rehabilitation. Exhibit 1.4 displays the eight districts. The central office consists of five main divisions and multiple offices. Within MnDOT's Engineering Services Division, the Office of Materials and Road Research has primary responsibility for setting and administering the policies that affect road rehabilitation. Its role involves coordinating pavement

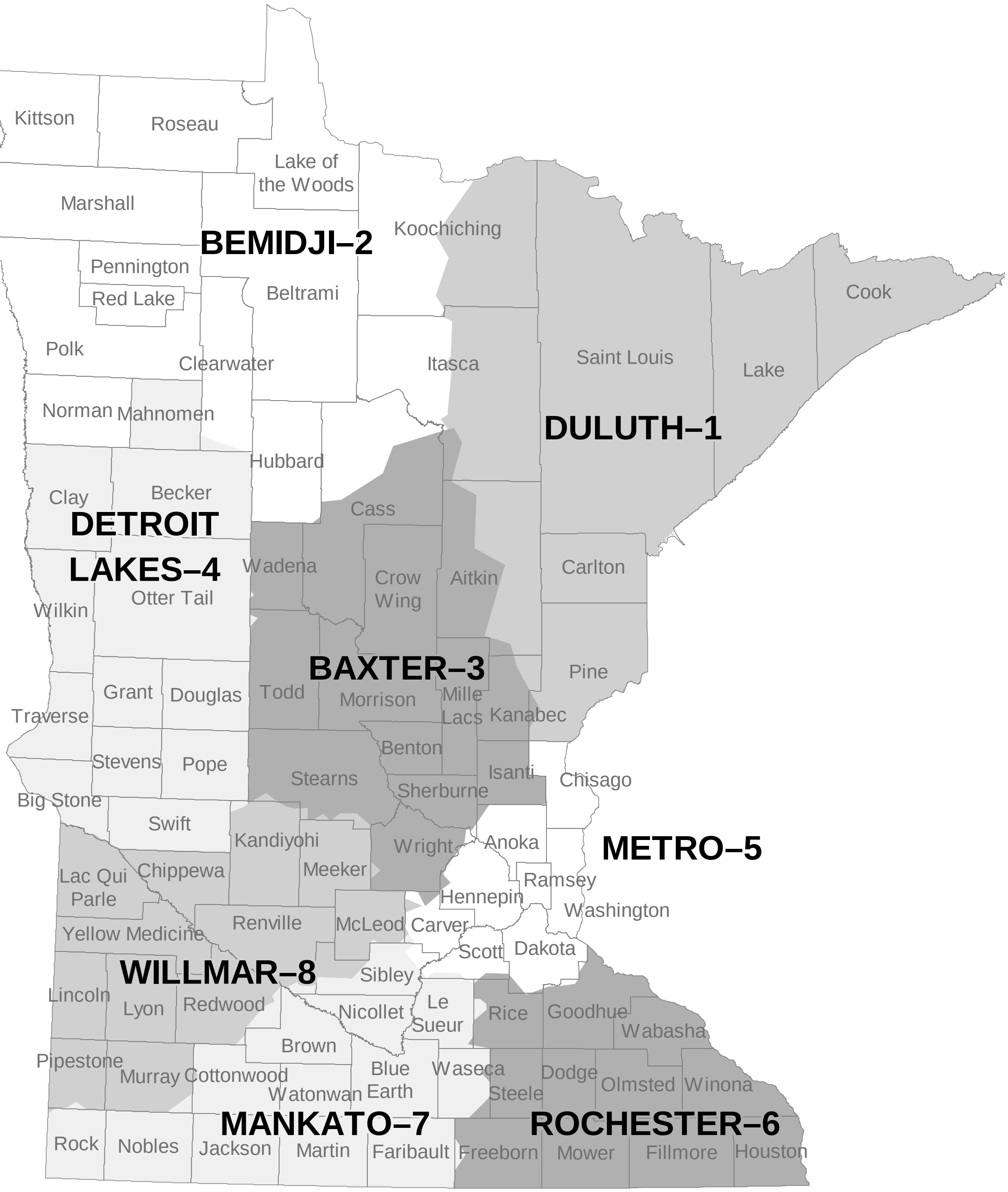
Exhibit 1.3: Examples of Common Pavement Rehabilitation and Maintenance

Bituminous	Description
Rehabilitation	
• Mill and overlay	New bituminous placed over existing bituminous. Existing bituminous may be ground off ("milled") prior to placement of the overlay.
• Bituminous overlay	New bituminous placed over existing concrete. Existing concrete may be broken into pieces and compacted into a flat surface before placing new bituminous.
• Reclaim and overlay	Existing bituminous is pulverized and mixed with underlying aggregate base materials to produce a new aggregate base. New bituminous is placed over this base.
Maintenance	
• Chip seal	Liquid bituminous applied to existing bituminous, immediately followed by an aggregate cover. Designed to ameliorate the effects of sun and water, while adding skid resistance to the pavement surface.
• Crack treatment	Includes both filling and sealing cracks. Crack filling is a temporary measure; bituminous is set into cracks to slow pavement deterioration until a more permanent fix is done. Crack sealing prevents water from entering a pavement structure via surface cracks and is performed using a special hot-poured sealant.

Concrete	Description
Rehabilitation	
• Whitetopping	New concrete placed over existing bituminous, with no measures taken to ensure or prevent a bond with existing bituminous. Conventional whitetopping is eight inches or more. Typically, there is no need to repair the underlying bituminous before placing the overlay, unless rutting is severe.
• Thin and ultra-thin whitetopping	New concrete placed over existing bituminous, ensuring a bond between the concrete overlay and existing bituminous. Concrete obtains support from the underlying bituminous, which must be in at least fair condition. Thin whitetopping is four to six inches thick (some sources say up to eight inches); ultra-thin whitetopping is two to four inches thick.
• Bonded concrete overlay	Three to four inches of new concrete placed over existing concrete, ensuring a bond between concrete overlay and existing concrete. Concrete obtains needed support from the underlying concrete, which must be in good condition.
• Unbonded concrete overlay	Four to 11 inches of new concrete placed over existing concrete and separated by a bond breaker, commonly consisting of hot-mix asphalt or a geotextile. Underlying concrete may be in poor condition.
Maintenance	
• Joint resealing	A preventive maintenance strategy in which joints between concrete panels are sealed with silicone, preventing surface water from entering and damaging the pavement.
• Minor concrete pavement rehabilitation	Primarily a preventive maintenance activity, often including "partial-depth" repairs, such as the replacement of deteriorated concrete.

SOURCES: Office of the Legislative Auditor, analysis of Asphalt Institute, *The Asphalt Handbook* (Lexington, KY: Asphalt Institute, 2007); Julie Vandenbossche, Nicole Dufalla, and Zichang Li, "A Revised Thin and Ultra-Thin Bonded Whitetopping Design Procedure" (paper submitted to the Transportation Research Board for publication, submission date: August 1, 2012); Minnesota Department of Transportation, *Pavement Design Manual* (St. Paul, 2010); National Concrete Pavement Technology Center, *Guide to Concrete Overlays* (Ames: Iowa State University, 2008); National Cooperative Highway Research Program, *Synthesis 338 Thin and Ultra-Thin Whitetopping* (Washington DC: Transportation Research Board, 2004); and Nobert Delatte, *Concrete Pavement Design, Construction, and Performance* (New York: Taylor & Francis, 2008).

Exhibit 1.4: Minnesota Department of Transportation Districts



SOURCE: Minnesota Department of Transportation.

analysis, design, construction, and rehabilitation, while providing technical assistance to MnDOT districts on these topics. The Operations Division consists of engineers and other personnel in each of MnDOT's eight districts. District staff plan and manage the highway maintenance and construction projects around the state.

MnDOT has eight districts around the state; the Metro District has the largest number of lane miles.

MnDOT is responsible for maintaining over 29,300 lane miles of trunk highway in Minnesota, consisting of interstate, federal, and state highways. District 5-Metro has the highest number of lane miles among the eight districts, as Exhibit 1.5 shows.

Exhibit 1.5: Trunk Highway Lane Miles by Minnesota Department of Transportation District, 2013

District	Interstate	U.S. Highway	State Highway	Total
1 - Duluth	394	1,034	2,280	3,708
2 - Bemidji	—	1,403	2,508	3,910
3 - Baxter	365	1,125	2,509	4,000
4 - Detroit Lakes	461	1,090	2,099	3,650
5 - Metro	1,405	940	1,726	4,071
6 - Rochester	825	1,257	1,609	3,691
7 - Mankato	585	712	1,989	3,286
8 - Willmar	—	1,101	1,898	2,999
Total	4,035	8,662	16,618	29,315

NOTES: Lane miles are a measure of road length; each lane mile represents an area one mile long and one lane wide. Amounts may not sum to totals due to rounding.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Transportation's Transportation Information System data.

Central Office and District Roles in Road Rehabilitation

MnDOT's process for developing rehabilitation projects has several components. A simplified description of the process is in Exhibit 1.6.

Identification of Road Problems

MnDOT's process for rehabilitation begins when district personnel identify road problems—generally years before any pavement decisions are made. Districts rely on multiple sources of information to identify road problems. One source is the **highway pavement management system**, which includes a database of historical road condition data that allows engineers to predict future road performance given certain pavement decisions and funding levels. It also provides a broad analysis of all roads in a district's road system. District materials engineers combine this information with their knowledge of current road conditions and may also receive road information from others, such as traffic engineers or crews that maintain the roads. Districts use these sources of information to compile a list of select projects for further development and scoping.

MnDOT district personnel identify road problems and plan and manage road rehabilitation projects.

Exhibit 1.6: Overview of Minnesota Department of Transportation's Process for Developing Road Rehabilitation Projects

Key Stages and Steps

Identification of Road Problems

- Use district knowledge of road history and current conditions
- Analyze historical data on road conditions, construction, and the pavement's remaining service life
- Determine list of candidate projects

Project Scoping

- Investigate potential issues affecting costs and project schedules
- Develop and analyze pavement alternatives
- Initiate preliminary design work
- Estimate project costs and analyze life-cycle costs

Project Programming

- Program and prioritize final projects and enter them into the State Transportation Improvement Program[a]
- Analyze project impacts on roadway performance goals and budget
- Complete project's final design plans

Project Letting

- Release bid package[b]
- Calculate engineer's estimate of project cost for comparison with bids
- Review bids
- Award contract to winning bidder

NOTES: The steps provide a general overview but are not a full list. In addition, the process may vary somewhat from district to district.

[a] MnDOT's State Transportation Improvement Program is the department's comprehensive four-year schedule of planned transportation projects across the state.

[b] The package includes all contractual documents that form the basis for contractor prices, including the project plan, proposal, and addendums.

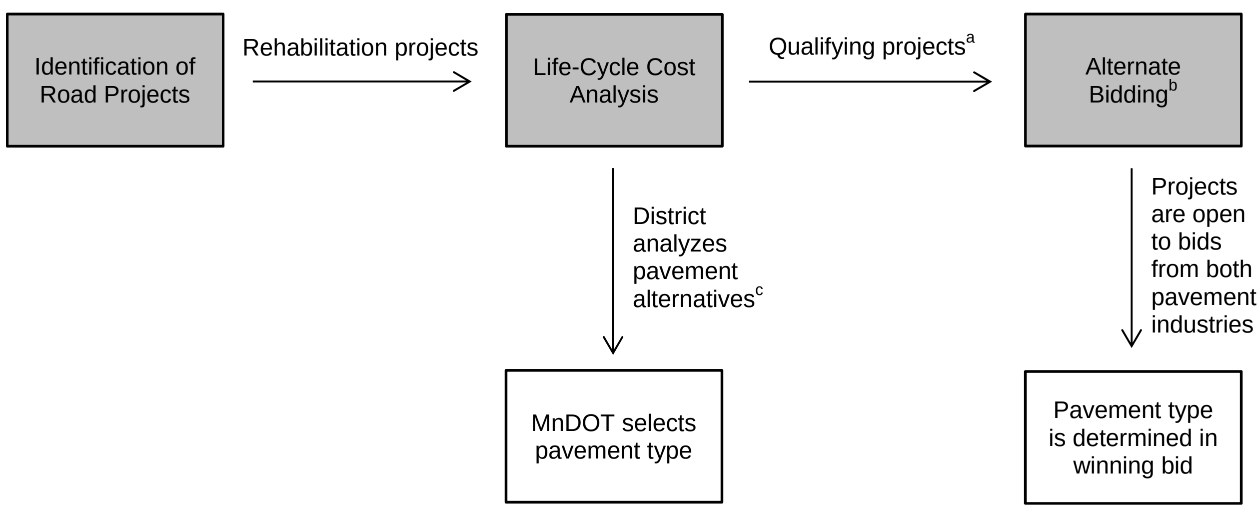
SOURCES: Office of the Legislative Auditor, analysis of interviews with materials engineers and soils engineers in Minnesota Department of Transportation's eight districts; Minnesota Department of Transportation, *MnDOT Scoping Process Narrative* (St. Paul, 2008), 1-17; and Sheila Cornelius, Office of Financial Management; Val Svensson, Project Management and Technical Support Office; Jim Weingartz, Project Management and Technical Support Office; and Joel Williams, Office of Construction and Innovative Contracting, Interview by OLA, in person, St. Paul, Minnesota, July 30, 2013.

Project Scoping

During the project scoping phase, districts explore all of the issues that might affect a project's cost and schedule. Districts also estimate costs of the projects to ensure that project costs align with available funding levels. After districts complete a project scoping report, they develop their preliminary designs. In preliminary design work, district personnel identify considerations such as whether an environmental review is needed or whether right-of-way issues exist.

Districts prepare a **materials design recommendation report** that includes all of a project's design information relating to pavement and geotechnical information. As part of this report, districts compare pavement alternatives using a **life-cycle cost analysis**, which identifies a project's low-cost alternative through an analysis of initial rehabilitation costs and expected future maintenance and rehabilitation costs.[5] Based on this analysis and other factors discussed within the materials design recommendation report, MnDOT districts select a pavement type. As Exhibit 1.7 shows, a subset of projects goes through a different process, known as alternate bidding, whereby MnDOT designs projects for bidding by both the bituminous and concrete industries. In alternate bidding, the pavement type is not chosen by MnDOT but is instead the one associated with the successful bid.

Exhibit 1.7: Key Decision Points for Selecting Pavement Type



[a] Projects are considered for alternate bidding when (1) their pavement alternatives are at least four inches thick and (2) the cost difference between the low-cost option and a pavement alternative of the opposite pavement type is less than 20 percent.

[b] Alternate bidding is a process whereby MnDOT lets projects for bidding from both the bituminous and concrete industries; it selects the winning bid, and the pavement type is the one associated with the successful bid.

[c] Districts determine a preferred pavement alternative by analyzing life-cycle costs and other relevant factors, including traffic conditions, geologic information, historical pavement conditions, and geometric design features. Districts report results of their analyses and describe their proposed work and preferred pavement alternative in a "materials design recommendation" report.

SOURCES: Office of the Legislative Auditor, analysis of Khani Sahebjam, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010; and Tim Andersen and Curt Turgeon, Pavement Engineering Section, interview by author, in person, St. Paul, Minnesota, September 3, 2013.

[5] *Minnesota Statutes* 2013, 174.185, requires MnDOT to perform life-cycle cost analyses for projects in the reconditioning, resurfacing, and road repair categories.

Project scoping requires numerous interactions among staff both within and outside a MnDOT district. Depending on the complexity of the project, interactions may occur throughout the project with the Federal Highway Administration, the Department of Natural Resources, the Minnesota Pollution Control Agency, local units of government, businesses, and others.

Project Programming

Districts set priorities among road projects based on each project's expected impact on road performance goals and funding. Districts choose to include or exclude projects from the State Transportation Improvement Program based on these priorities.[6] Districts develop each project's final design plans. This includes completing work on the issues identified during the project's preliminary design. For projects going through alternate bidding, districts develop separate design plans for each of the pavement types.

Project Letting

After completion of the final designs, MnDOT's Project Management and Technical Support Office prepares projects for bidding. The office forwards the plans to various groups for review, and it prepares and releases a bid package for each project, including all of the contractual items necessary for establishing contractor prices. At this point, the project is "let" or put out for bids. MnDOT prepares an "engineer's estimate," which MnDOT uses to ensure the reasonableness of incoming bids. After the department receives and analyzes bids, MnDOT's Office of Construction and Innovative Contracting reviews the bid analysis and recommendations, determines that all contract requirements have been adequately addressed, and awards the contract to the winning bidder.[7] Typically, the award goes to the contractor who submits the low-cost bid.[8]

Resources for Road Work

MnDOT's contracts for road pavement projects let in fiscal year 2013 amounted to $583 million.[9] This includes contracted spending on new construction and reconstruction as well as on road rehabilitation. From fiscal year 2009 to fiscal

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[6] MnDOT's State Transportation Improvement Program is the department's comprehensive four-year schedule of planned transportation projects across the state. Projects in the plan must be consistent with MnDOT's *Statewide Multimodal Transportation Plan,* which is required by *Minnesota Statutes* 2013, 174.03, subd. 1. (2).

[7] MnDOT's Office of Construction and Innovative Contracting also offers technical support to districts regarding contracts, labor provisions, and other requirements.

[8] *Minnesota Statutes* 2013, 161.32, subd. 1.b, requires MnDOT to award contracts for work on the trunk highway system to the lowest responsible bidder. Subd. 1.f allows an alternative whereby the contract is awarded to the contractor offering the best value.

[9] Spending is measured as the sum of all contract values for this set of road projects; it does not reflect the projects' final costs. Contract values incorporate contractors' costs associated with the project(s), including materials, labor, equipment, overhead, and profit; they include both paving and related work, such as guardrails or curbs and gutters. Data exclude projects with no reported contract value, no reported mileage, or a reported mileage of zero. In some cases, MnDOT lets multiple projects jointly under a single contract.

year 2013, total contracted spending on pavement construction, reconstruction, and rehabilitation increased 36 percent.

In fiscal year 2013, MnDOT's contracts for road rehabilitation amounted to $365.5 million.

Most of MnDOT's contracted pavement spending is on road rehabilitation. In fiscal year 2013, MnDOT contracts for rehabilitation totaled $365.5 million, or 63 percent of its contracted pavement spending. Exhibit 1.8 shows the amount of contracted spending on rehabilitation by district and how much that represents of total contracted pavement spending.

Exhibit 1.8: Total Pavement Spending and Road Rehabilitation Spending in Contracts by District, Fiscal Year 2013

District	Contracted Spending on All Pavement Projects (in millions)	Contracted Spending as a Percentage of Statewide Spending	Contracted Spending on Rehabilitation Projects (in millions)	Contracted Spending on Rehabilitation as a Percentage of Spending on All Projects
1 - Duluth	$ 87.6	15%	$ 50.7	58%
2 - Bemidji	12.0	2	10.3	86
3 - Baxter	61.4	11	50.1	82
4 - Detroit Lakes	55.8	10	38.9	70
5 - Metro	170.5	29	69.8	41
6 - Rochester	111.2	19	96.9	87
7 - Mankato	53.5	9	22.1	41
8 - Willmar	31.2	5	26.7	85
Statewide	$583.2	100%	$365.5	63%

NOTES: Spending is measured as the sum of all contract values for this set of road projects; it does not reflect the projects' final costs. Contract values incorporate contractors' costs associated with the project(s), including materials, labor, equipment, overhead, and profit; they include both paving and related work, such as guardrails or curbs and gutters. Data exclude projects with no reported contract value, no reported mileage, or a reported mileage of zero. In some cases, MnDOT lets multiple projects jointly under a single contract.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Transportation Contract Management System data.

MnDOT's contracted spending for road rehabilitation represented 63 percent of its total contracted pavement spending.

Type of Pavement Used for Rehabilitation

Over the last five years, the number of rehabilitation projects using bituminous pavement greatly exceeded the number using concrete. Of 388 rehabilitation projects from fiscal year 2009 to fiscal year 2013, 343 (88 percent) were bituminous, and 37 (10 percent) were concrete; the remaining 2 percent were a mix of bituminous and concrete.[10]

Contracted spending on bituminous rehabilitation increased annually from fiscal year 2009 to fiscal year 2013 and was greater than contracted spending on

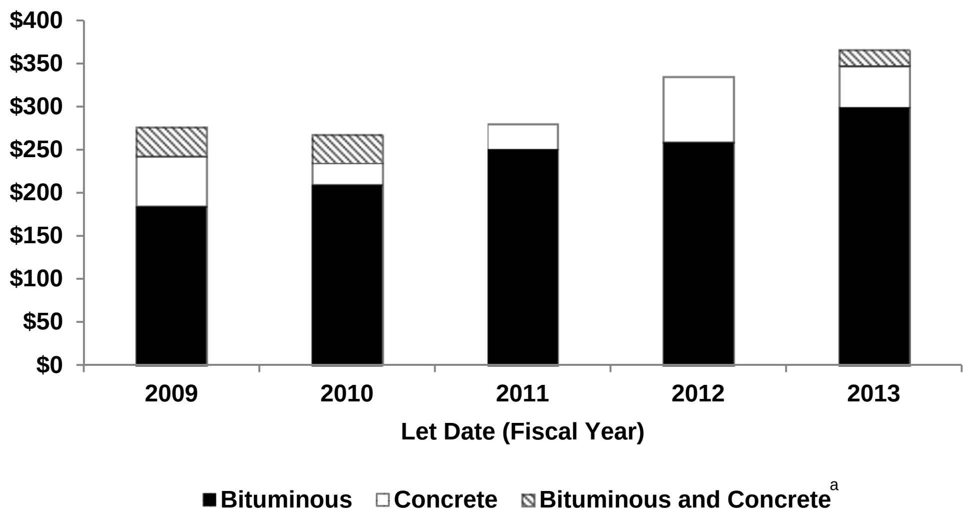
[10] Projects with a mix of pavement types included those that were divided into two sections with one section involving bituminous and the other concrete.

concrete rehabilitation, as Exhibit 1.9 illustrates. Road rehabilitation spending from contracts for bituminous averaged approximately $241 million per year over those five years, compared with a $48 million per year average for concrete pavements. Contracts for spending on projects with a mix of pavement types averaged about $17 million per year.

Of 388 rehabilitation projects between fiscal years 2009 and 2013, about 88 percent were bituminous and about 10 percent were concrete.

Exhibit 1.9: Contracted Spending on Road Rehabilitation by Pavement Type, Fiscal Years 2009-2013

In Millions



NOTES: Spending is measured as the sum of all contract values for this set of road projects; it does not reflect the projects' final costs. Contract values incorporate contractors' costs associated with the project(s), including materials, labor, equipment, overhead, and profit; they include both paving and related work, such as guardrails or curbs and gutters. Data exclude projects with no reported contract value, no reported mileage, or a reported mileage of zero. In some cases, MnDOT lets multiple projects jointly under a single contract.

[a] Refers to projects using both pavement types, such as those divided into two sections with one section involving bituminous and the other concrete.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Transportation Contract Management System data.

PAVEMENT INDUSTRIES

In Minnesota, pavement contractors bid to construct MnDOT's road rehabilitation projects. Two industry associations represent most of the contractors and interact with MnDOT regarding pavement policies. Each of them has voiced concerns about MnDOT practices that they feel affect their share of the market. In subsequent chapters, we address some of the concerns.

One industry association is the Concrete Paving Association of Minnesota. Its members include paving and rehabilitation contractors, suppliers of aggregate and cement, and equipment manufacturers. The association's stated purpose is to promote the use of concrete pavements. In discussions during this evaluation, the association's executive director described several concerns. He asserted to us that Minnesota's roads are increasingly in poor condition because inadequate funding has led to an over reliance on thinner bituminous overlays because those were what MnDOT districts could afford. He also asserted that MnDOT is reluctant to use new designs with thinner concrete, despite results of studies the industry said supports these designs. Finally, he claimed that MnDOT's pavement management system leads districts away from options such as whitetopping and toward thin or medium bituminous overlays to improve road conditions for the short-term due to the need to stay within a limited budget.

The second industry association is the Minnesota Asphalt Pavement Association. It is a trade association with members who are bituminous contractors and associates, such as equipment and gravel suppliers. Its stated mission is to be a leader in the transportation industry and support its members in ways to benefit their customers. When asked during this evaluation about concerns with pavement selection in Minnesota, association representatives asserted that MnDOT needs to update and standardize its analysis of life-cycle costs so that different people with the same information make similar pavement decisions. They also asserted that MnDOT needs a list of department-approved pavement alternatives to guide MnDOT districts in pavement selection. Further, they claimed that MnDOT does not adequately factor into its process environmental considerations that would lead to increased recyclable materials in pavements.

2 Recommended Practices for Selecting Type of Pavement

In this chapter, we describe practices recommended for a process of selecting pavement for road rehabilitation projects. How the process is designed and works is important because it determines the pavement type, the road work to be done, and (for most projects) the set of potential contractors that bid on rehabilitation projects.

The practices we describe in this chapter are based on an extensive review of national literature on this topic. In identifying standards for selecting pavement type, much of the literature does not differentiate between standards for *rehabilitating* roads versus those for *constructing new* roads or *reconstructing* them. We believe it is reasonable to assume that the standards included here apply equally to all these groups of projects. In this report, we compare the recommended practices to the process used by the Minnesota Department of Transportation (MnDOT) to select pavement type for rehabilitating roads. The report does not examine MnDOT's process for construction or reconstruction projects.

We examined national literature to identify recommended practices for selecting pavement type.

Our key sources are reports from leading research agencies. One is the National Cooperative Highway Research Program, which is part of the Transportation Research Board of the National Academies. The Transportation Research Board is a major division of the National Research Council and is viewed as a leader in objective transportation research. In 2011, the board's National Cooperative Highway Research Program published a guide that provides detailed advice on the entire process of selecting pavement type.[1] We used this guide as a foundation for identifying recommended practices and supplemented it with reports from and policies of the Federal Highway Administration in the U.S. Department of Transportation, as well as reports and documents from others.[2] Although we reviewed reports from within the concrete and bituminous industries, we did not rely on them as main sources for recommended practices.

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[1] National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011).

[2] Some of the key sources are: Federal Highway Administration, *Life-Cycle Cost Analysis Primer* (Washington DC: U.S. Department of Transportation, August 2002); Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design, In Search of Better Investment Decisions* (Washington DC: U.S. Department of Transportation, September 1998); Federal Highway Administration, *Technical Advisory: Use of Alternate Bidding for Pavement Type Selection,* December 20, 2012; and U.S. Government Accountability Office, *Federal-Aid Highways: Improved Guidance Could Enhance States' Use of Life-Cycle Cost Analysis in Pavement Selection* (Washington DC: U.S. Government Accountability Office, June 2013).

In what follows, we lay out the primary practices for selecting pavements, as recommended by the literature we examined. We also compare MnDOT with two of these recommended practices. The remaining practices are discussed in Chapters 3 and 4.

PRACTICES FOR SELECTING PAVEMENT TYPE

Based on our literature review, we identified five primary practices for a process of selecting pavement type. The five are: (1) develop policies on when and how the selection process will be applied, (2) identify potential pavement alternatives to be considered, (3) apply a life-cycle cost analysis to the alternatives, (4) evaluate pavement alternatives, and (5) develop policies for alternate bidding.[3] Exhibit 2.1 displays the five practices and their component parts.[4]

In the rest of this chapter, we examine two of the five recommended practices: (1) develop policies on when and how the process will be applied and (2) identify potential pavement alternatives. Chapter 3 analyzes practices related to life-cycle cost analyses and evaluating factors pertaining to pavement alternatives. Chapter 4 examines practices related to alternate bidding.

Regarding the two practices examined in this chapter, we conclude:

- **Overall, the Minnesota Department of Transportation meets most recommended practices for determining when to apply its process on selecting pavement type, but it does not fully meet practices related to identifying pavement alternatives.**

The remainder of this chapter defines the two recommended practices and evaluates how MnDOT compares with them.

Developing a policy on when and how to apply a pavement selection process is a recommended practice.

DEVELOP A POLICY FOR SELECTING PAVEMENT

It is important to develop a policy on when and how to apply the process on selecting pavement type. Such a policy determines the projects governed by the process and those that are exempt. This is important because the process for selecting pavement type is lengthy, requires significant effort, and should be reserved for projects of a scope that warrants the time and effort needed.

[3] In alternate bidding, the pavement type is determined in the bid of the contractor who was awarded the project.

[4] A sixth practice on policies for alternative contracting is also included in the literature. It refers to alternatives to the customary "design-bid-build" contracting arrangement wherein the transportation agency completes the design for a road project (including selecting the type of pavement) and submits it for bidding; under this arrangement, contractors bid to construct the project, assume no responsibility for performance of the pavement after construction, and are not involved in selecting pavement type. However, alternatives to the customary contracting approach involve much more than pavement selection, and analyzing such alternatives in Minnesota is beyond the scope of this evaluation.

Exhibit 2.1: Recommended Practices for Selecting Pavement Type for Road Rehabilitation

Develop a Policy for Selecting Pavement Type

Consider the following factors:

- Project cost and length
- Traffic type and volume
- Road system classification
- Presence of bridge structures
- Pavement quantity
- Lane modifications or additions
- Ramps
- Acceleration and deceleration lanes

Identify Potential Pavement Alternatives

- Determine feasible pavement alternatives
- Develop future rehabilitation and maintenance strategies
- Use a pavement-type selection committee to systematically consider pavement alternatives

Apply Life-Cycle Cost Analyses

- Use a minimum 30-year analysis period
- Apply appropriate discount rates to compute the present value of costs
- Remove the effects of inflation using real dollars
- Base costs on historical bid data and current market prices
- Calculate salvage value of pavement
- Calculate supplemental costs
- Calculate user costs where appropriate
- Account for uncertainty of data used in life-cycle cost analysis

Evaluate Pavement Alternatives

- Use a formal decision-making tool to jointly evaluate economic and noneconomic factors that affect competing pavement alternatives
- Evaluate economic factors:
  - ✓ Initial costs
  - ✓ Rehabilitation costs
  - ✓ Maintenance costs
  - ✓ User costs
  - ✓ Life-cycle costs
- Evaluate noneconomic factors:[a]
  - ✓ Roadway geometrics and pavement continuity
  - ✓ Traffic during construction
  - ✓ Availability of local materials and experience
  - ✓ Safety considerations

Develop Policies for Alternate Bidding

- Identify a broad range of potential pavement alternatives
- Develop criteria to identify feasible pavement alternatives at the project level
- Develop suitability criteria on when to use the process
- Establish rehabilitation and maintenance strategies for each pavement alternative
- Set guidelines for conducting a life-cycle cost analysis
- Develop guidelines for achieving equivalency of pavement alternatives
- Establish criteria for determining a factor to adjust bids
- Use unbiased project specifications
- Involve industry in developing and reviewing the alternate bidding process
- Implement alternate bidding, including a periodic review of the process

NOTE: A practice on developing policies for alternative contracting is also recommended in the literature, but the practice involves more than pavement selection and, therefore, is not evaluated in this report.

[a] The list of recommended noneconomic factors also includes: continuity of adjacent pavements and lanes, conservation of materials and energy, local government preferences, stimulation of competition among paving industries and materials suppliers, noise issues, subgrade soil characteristics, experimental materials or design concepts, future needs, maintenance experience and equipment, industry capability to perform the required work, and sustainability.

SOURCES: Office of the Legislative Auditor analysis of National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011); Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design, In Search of Better Investment Decisions* (Washington DC: U.S. Department of Transportation, September 1998); and Federal Highway Administration, *Life-Cycle Cost Analysis Primer* (Washington DC: U.S. Department of Transportation, August 2002).

When setting its policy, an agency should consider ten factors, such as project cost and length. Exhibit 2.2 lists the ten factors. However, the literature's recommendation is somewhat vague in that it does not detail how to use the ten

Exhibit 2.2: Factors to Consider in Developing Policies on Pavement Selection

- Project cost
- Project length
- Traffic type
- Traffic volume
- Road system classification
- Pavement quantity
- Presence of bridge structures
- Lane modifications or additions
- Ramps
- Acceleration and deceleration lanes

SOURCE: National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011), 2.

factors. Despite this difficulty, we attempted to compare the ten factors with MnDOT's official policy on when to analyze life-cycle costs for rehabilitation projects.[5] MnDOT developed its policy to comply with state law.[6] From this comparison, we found that:

- **The Minnesota Department of Transportation's policy for determining which rehabilitation projects must go through a process for selecting pavement type and a life-cycle cost analysis largely meets the components of the recommended practice.**

We do not know what went into MnDOT's deliberations as it developed the policy. However, the policy contains direct references to four of the recommended factors: project length, pavement quantity, lane additions, and acceleration/deceleration lanes. Beyond that, the policy indirectly addresses four others. Traffic type, traffic volume, project cost, and road system classification are addressed indirectly in that the policy requires analyses for *all* pavement preservation projects in the categories of reconditioning, resurfacing, and road repair. The only exceptions to the requirement for life-cycle cost analyses are for short rehabilitation projects of less than two miles or those with two inches or less of pavement. This means districts must conduct the analyses regardless of project cost, road system classification, or whether the roads have low or high traffic volumes. Although literature recommends that the policy consider bridge

[5] The policy is the foundation for MnDOT's process of selecting pavement type for road rehabilitation projects. It is reflected in the following MnDOT technical memorandum: Khani Sahebjam, Deputy Commissioner and Chief Engineer, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010.

[6] *Minnesota Statutes* 2013, 174.185, requires MnDOT to analyze the life-cycle costs of certain road rehabilitation projects.

structures and ramps, MnDOT's policy does not specifically refer to the presence of bridges or ramps.[7]

IDENTIFY POTENTIAL PAVEMENT ALTERNATIVES

It is important to identify a full set of feasible pavement alternatives and determine for each the rehabilitation and minor maintenance that will be needed over its life cycle.

Another recommended practice for selecting pavement type is to identify potential pavement alternatives for road projects. The practice involves three steps: (1) determine feasible pavement alternatives, (2) develop the rehabilitation and minor maintenance strategies (and their timing) that will be needed during each alternative's life cycle, and (3) use a pavement-type selection committee with broad representation to systematically consider alternatives. We examined MnDOT's process for selecting pavement alternatives and found that:

- **The Minnesota Department of Transportation's process for identifying potential pavement alternatives for road rehabilitation meets some but not all recommended practices.**

In what follows, we examine each of the three steps and their components. We also compare them with MnDOT processes.

Determine Feasible Pavement Alternatives

The first step is to identify a set of feasible pavement alternatives. This is needed to determine the pool of viable pavement alternatives that should be considered for road rehabilitation. The step involves using data on: (1) conditions and history of the existing pavement, including pavement distresses; (2) the amount and type of traffic; (3) the functional classification of the road; and (4) peripheral features, such as overhead clearances. Determining viable alternatives also requires considering innovative approaches that may be identified by the department, pavement industries, or national research. In comparing MnDOT processes with recommended practices, we found:

- **The Minnesota Department of Transportation uses data analyzed centrally to identify feasible pavement alternatives, but the data are incomplete.**

MnDOT has not defined a full range of feasible pavement alternatives from which districts may identify suitable alternatives for a specific road project. MnDOT districts supplement data that are available centrally with data and experiences of their own. In the next sections, we describe the recommended practices for identifying feasible alternatives and examine MnDOT's process related to each practice.

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[7] One can infer the policy does not apply to bridges because it applies specifically to "pavement preservation" projects, which MnDOT tends to separate from bridge projects.

Pavement Conditions and History

MnDOT has a "pavement management system" with data on road conditions.

The conditions of the road, and how the pavement has performed historically, help identify feasible pavement alternatives. In their materials design recommendation reports, MnDOT district personnel explain data on current and historical road conditions. Districts also compare measures of pavement condition over time.

Road condition data come from MnDOT's pavement management system. MnDOT uses a specialized van to gather data for measuring pavement condition. Each year the van travels every mile of trunk highways in both directions. The van collects measurements on pavement roughness using laser technology and records images of a sample of pavement surface for each road segment. MnDOT uses the data gathered by the vehicle to establish the condition of all segments of pavement on the trunk highway system. MnDOT evaluates pavement quality using four performance measures: ride quality index, surface rating, pavement quality index, and remaining service life.[8] Exhibit 2.3 describes the measures that MnDOT takes.

One of the functions of MnDOT's pavement management system is to help predict future road conditions and needs based on historical road performance data. For each segment of road, the system has a set of historical data on road performance and construction. Based on these data, it predicts road quality and pavement distress levels into the future. The system includes "decision trees" that recommend certain road treatments triggered by a road's construction history as well as data on condition and pavement distresses. For instance, if an arterial road with curbs and certain distresses falls below a threshold on the ride quality index, the decision tree may suggest a rehabilitation of a thick mill and overlay. The decision trees offer multiple possible results, from "do nothing" to reconstruct the road; the results contain both rehabilitation and maintenance. The pavement management system also identifies the combination of projects within a district that provides optimal cost-effectiveness given the funding available for that district's road system.

The system helps identify road rehabilitation options, but it does not include every viable option.

However, MnDOT's pavement management system is incomplete because it does not contain some viable rehabilitation options. For instance, the decision tree for concrete does not include whitetopping, and the decision tree for bituminous does not include full-depth reclamation (whereby the existing pavement and a portion of the underlying base are pulverized and blended to form a new base layer). MnDOT officials told us one of the limitations of the pavement management system is that the van collects only surface data. Adding thick whitetopping as an outcome on the decision tree is possible. However, a rehabilitation such as thin whitetopping requires data on thickness and condition

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[8] The ride-quality index measures smoothness of the road. MnDOT has estimated a mathematical relationship between (1) roughness data gathered by the van's lasers and (2) travelers' subjective perceptions of smoothness. The surface rating measures defects on the pavement surface as captured in digital images of the road surface and analyzed and weighted by MnDOT technicians to determine the type and severity of all defects. The pavement quality index is a single measure of the pavement condition; it is calculated by taking the square root of the product of the ride-quality index and the surface rating. Finally, the remaining service life is an estimate of how long a pavement will last until it needs a major rehabilitation or reconstruction.

Exhibit 2.3: Minnesota Department of Transportation Measures of Pavement Condition

Measure	What Is Measured	Scale	Data Source
Ride Quality Index	Smoothness as perceived by travelers	0.0 - 5.0	Roughness data gathered with lasers by MnDOT van[a]
Surface Rating	Pavement distress	0.0 - 4.0	Images gathered by MnDOT van and rated by MnDOT staff
Pavement Quality Index	Summary measure of pavement condition	0.0 - 4.5	Calculated directly from the ride quality index and the surface rating[b]
Remaining Service Life	Years until the end of a pavement's design life[c]	0.0 - 35	Regression estimates using historical ride quality index data

[a] MnDOT uses roughness data gathered by the vehicle's lasers to estimate an ordinary traveler's perception of smoothness over certain road conditions. MnDOT makes this estimate using an empirical relationship between perceived smoothness and the roughness data it gathers.

[b] The pavement quality index is the square root of the product obtained from multiplying the ride quality index by the surface rating.

[c] Remaining service life is an estimate of the number of years until a pavement's ride quality index reaches a value of 2.5, which is generally considered the end of a pavement's design life.

SOURCES: Minnesota Department of Transportation, Office of Materials and Road Research, Pavement Management Unit, *2012 Pavement Condition Annual Report* (St. Paul, March 2013); and Khani Sahebjam, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010.

of pavement layers, which MnDOT says would be difficult to program into the pavement management system.

MnDOT officials said that the pavement management system establishes a level of investment for a road segment, but the system does not identify the appropriate road fix. MnDOT relies on its district personnel to identify appropriate pavement alternatives at the time they scope and design rehabilitation projects.

MnDOT relies on its district personnel to identify appropriate fixes for road problems.

Data from the pavement management system represent a starting point in identifying feasible pavement alternatives, according to MnDOT district staff. As part of this evaluation, we interviewed materials engineers in each of MnDOT's eight districts. The engineers told us that they use results from the pavement management system as an important input, but by itself, the pavement management system is not sufficient. They said they balance information from the pavement management system with their own awareness of road needs within their district's road system.

Furthermore, some materials engineers said they found it difficult to identify concrete rehabilitation strategies involving thin concrete. They said that MnDOT's approved standards did not include designs for thin concrete, and they were reluctant to consider designs that had not been independently researched or did not have historical performance data. As described later in this report, recent changes to MnDOT's concrete design guides may address this difficulty, at least in part.

RECOMMENDATION

The Minnesota Department of Transportation should identify a full range of feasible pavement alternatives for road rehabilitation projects.

MnDOT's work on identifying a fuller range of feasible pavement alternatives is underway.

MnDOT has historical data on certain pavement alternatives, but it needs to formally identify all feasible alternatives. Work on determining feasible pavement alternatives should be ongoing. As an example of how this is underway, in early 2014, MnDOT adopted design standards for thin whitetopping, which is an important step toward achieving a full range of pavement alternatives. Chapter 5 further describes this change. Until this point, MnDOT's design approach for whitetopping was imprecise because it was based on standards for *new* concrete pavement. MnDOT districts have little historical data on thin whitetopping or its performance. MnDOT should update its current design standards for unbonded concrete overlays over existing concrete. MnDOT has not developed detailed design guides or performance information for the process of "rubblizing" concrete pavements followed by bituminous overlays.[9] Placing certain strategies on the pavement management system decision tree can be problematic. MnDOT should address the deficiencies by developing the means and procedures to make a full range of rehabilitation strategies available for consideration. This is important because district materials engineers take their lead from the department's standards and policies.

Pavement Distresses

Identifying feasible pavement alternatives also depends on the type of road distress, how it was caused, and its effects on the pavement's structural and functional capacities. Identifying road distresses can involve taking core samples of the road layers, evaluating drainage and other concerns on-site, and using nondestructive testing methods.[10]

MnDOT districts identify pavement distresses in their materials design recommendation reports. Pavement wears out over time because of the combined effects of traffic and environmental influences, such as breakdown from freeze-thaw cycles. The districts consider the factors that caused the distress and recommend pavement alternatives to address the deterioration. Some of the common road distresses that require rehabilitation are displayed in Exhibit 2.4.

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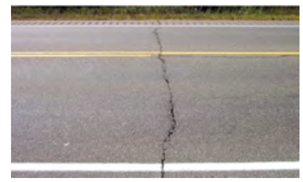
[9] Rubblizing involves a machine that breaks existing concrete into small pieces to form a new base in advance of a bituminous overlay.

[10] Nondestructive testing provides information on conditions below a pavement surface without breaking through it. It includes radar equipment to detect subsurface properties and "deflection" measuring equipment to estimate layer strengths and other properties.

Exhibit 2.4: Examples of Pavement Distress Measured by the Minnesota Department of Transportation

	Description	Example
Bituminous		
Transverse cracking	Crack predominantly perpendicular to the centerline of the road	
Alligator cracking	Series of interconnected cracks forming many-sided, sharp-angled pieces that are six inches or less across	
Concrete		
Transverse joint spalling	Cracking, breaking, chipping, or fraying along joint running perpendicular to the centerline	
Cracked and broken panel	Cracks, at least two feet long, dividing a concrete panel into four or more pieces	

SOURCE: Minnesota Department of Transportation, Office of Materials and Road Research, Pavement Management Unit, *MnDOT*, *Pavement Distress Identification Manual* (St. Paul, 2011), 4-29.

Traffic

Traffic type and volume affect which pavement alternatives are feasible. MnDOT's materials design recommendation reports for each road project provide traffic data and estimates of future traffic. The districts design pavement alternatives to carry certain traffic, reflecting both volume and vehicle loads. Traffic volume is typically measured in levels of annual average daily traffic. To reflect differences among vehicles by number of axles, loads, and body configuration, MnDOT classifies vehicles and estimates their "equivalent single axle loads." The equivalent single axle load is an estimate of the damage to pavement caused by different wheel and axle loads. MnDOT has calculated an equivalent single axle load for bituminous and a separate one for concrete pavement.

Functional Classification

The functional classification of roads is important because some pavement alternatives are more or less appropriate for certain classifications. MnDOT groups roads into one of three classes of roads according to the character of service they provide, such as whether traffic is local or long distance. For instance, "arterial" roads move large volumes of traffic and are suitable for statewide or interstate travel. "Collector" roads have somewhat lower traffic volumes and speeds than arterials. The third classification is "local" roads, which are for low speeds, low traffic volumes, and short trips. In MnDOT's highway project development process, the department requires for most projects a design memorandum that provides project information, including the functional classification.[11] In addition, in the materials design recommendation reports developed for each road rehabilitation project, MnDOT districts identify the characteristics of the road's functional classification.

Peripheral Features

According to the literature, the identification of feasible pavement alternatives should also include consideration of a road's peripheral features. Such features include guardrails, curbs and gutters, overhead clearances, and devices to control traffic. These features can affect the feasibility of pavement alternatives. For instance, pavement alternatives that require significant increases in the grade may not be suitable for road segments with limited overhead clearance due to bridges. In materials design recommendation reports, MnDOT districts describe the pertinent features of the roadway segment.

Develop Future Rehabilitation and Maintenance Strategies

It is recommended that transportation agencies use data from past road projects to estimate the type of future rehabilitation and maintenance that is likely to be needed for each pavement alternative.

Once feasible pavement options are developed, the next step in identifying pavement alternatives is to develop the life-cycle strategies for each pavement option. The specific purpose of this step is to identify the timing and type of rehabilitation and minor maintenance needed over the time period the pavement alternatives are to be analyzed. Data from past projects, such as what is maintained in a pavement management system, should preferably be used to estimate the type of road work that can be expected over the full life cycle of each pavement alternative, as well as when the work is likely to be needed. However, if historical data are insufficient, other information sources may be used, such as national design guides, the practical experience of agency staff, and other states' research. The information involves determining the "service life"

[11] MnDOT requires all road pavement projects to have a design memorandum *unless* they are: preventive maintenance projects; bituminous overlays with two inches or less of bituminous for roads on the National Highway System; or bituminous overlays or reclamation projects with increases in the pavement profile of two inches or less on roads that are not part of the National Highway System.

for each alternative as well as the schedule and extent of future rehabilitation and maintenance.[12] We found that:

- **The Minnesota Department of Transportation largely meets recommended practices for developing future rehabilitation and maintenance strategies for pavement alternatives.**

MnDOT relies on its district personnel to develop future rehabilitation and maintenance strategies for pavement alternatives. MnDOT's technical memo directs districts to establish their own schedule of maintenance and rehabilitation for pavement alternatives. It says the districts are to determine activity timing based on their own experience, results from the pavement management analysis of road conditions, or Appendix E in MnDOT's *Pavement Design Manual*.

Most materials engineers in MnDOT districts told us that they do not follow a predetermined rehabilitation and maintenance schedule because each road has different needs. They said they used their own professional judgment to schedule maintenance and rehabilitation, although most reported using as a starting point the guidance offered in MnDOT's *Pavement Design Manual* or the alternate bid maintenance schedules developed in 2011.[13]

The materials and soils engineers from one district explained that, to identify the type and timing of needed rehabilitation and maintenance, they begin with data from the pavement management system; they corroborate it with their own observations and information from the district's maintenance staff who encounter deterioration and defects while maintaining roads. They analyze the last rehabilitation and its durability on a particular road segment and track deterioration rates by levels of traffic for the various rehabilitation strategies. To set priorities among projects, they assign weights to criteria, including condition, traffic volume, and goods movement of road segments. They look at average daily traffic levels and road conditions to make judgments about scheduling rehabilitation and maintenance.

Materials engineers in MnDOT districts said the level of funding available may force them to select pavement alternatives that cost less initially but are not as long lasting.

All eight materials engineers indicated that available funding also affects which projects are completed in any given year. The timing of a rehabilitation may depend upon available funding, trends in conditions on other roads, and other planned construction in the district. Some types of rehabilitation improve roads for the short term, while others provide long-term fixes. Materials engineers reported that, depending on the amount of funding available, they may have to

[12] The service life is the expected time that the road will remain in service between the initial rehabilitation and the next major rehabilitation. Due to climate, construction quality, and traffic loads, the actual service life of a road segment may be shorter or longer than for what it was designed.

[13] MnDOT's *Pavement Design Manual* contains an appendix from 1994 with ranges of certain rehabilitation's expected service lives that vary by whether the road is (1) in good, fair, or poor condition and (2) designed for high, medium, or low traffic volumes. It does not display at what pavement age (or range of ages) minor maintenance should be undertaken. The 2011 alternate bid maintenance schedules were developed by MnDOT's Pavement Engineering Section to ensure that the timing for future rehabilitation and maintenance was similar in projects that are let for bidding by both pavement industries.

select pavement alternatives that cost less initially but are not as long-lasting, which may lead to more costs in the long run.

As described earlier, MnDOT has not fully identified all feasible pavement alternatives. For pavement strategies that are rarely used, districts are less likely to have sufficient data to develop the timing and type of future rehabilitation and maintenance strategies. Some district materials engineers said they seek guidance from other districts or MnDOT's central office when they lack sufficient local information.

Use a Committee

A third step recommended for identifying potential pavement alternatives is to use a pavement-type selection committee. According to the literature, the committee's main purpose is to identify a broad range of pavement alternatives that can be considered systematically and without bias. It is not intended as a group that routinely selects pavement type for an individual project. Instead, the literature suggests the committee would maintain a list of possible pavement strategies; address nonengineering concerns, such as on pavement sustainability; intervene on projects where no pavement alternative presents a clear advantage; and periodically review the entire process for selecting pavement type. Further, literature recommends that the committee have broad representation, including personnel from design, materials, construction, and maintenance as well as a formal method for receiving input from pavement industries. It does not specify whether such a committee ought to be convened on a statewide basis or on a districtwide level. In comparing this step with MnDOT's process, we found that:

- **The Minnesota Department of Transportation lacks a broad-based committee to identify potential pavement alternatives, as recommended in the literature, but it uses other methods to accomplish most of the same recommended functions.**

MnDOT does not have a committee to perform the recommended functions. However, the Pavement Engineering Section within MnDOT's Office of Materials and Road Research fulfills this role in many respects. In our judgment, this section's work is the equivalent of the recommended committee. The Pavement Engineering Section determines the possible strategies that could become pavement alternatives in rehabilitation projects. For example, in 2013 it drafted "Pavement Type Selection," a chapter that is intended to eventually be included in MnDOT's *Pavement Design Manual.* Although still a draft in early 2014, the chapter contains information on the department's process for selecting pavement type as well as pavement design standards for both bituminous and concrete designs.

The Pavement Engineering Section is also responsible for ongoing reviews of MnDOT's process for selecting pavement type. Section staff have regular interactions with representatives of both the concrete and bituminous industries. As an example, both industries reviewed and presented comments on the aforementioned draft "Pavement Type Selection" chapter. Additionally, the Pavement Engineering Section sought and received industry input on alternate bid projects, which are designed for bidding from both paving industries. For each such project let in 2013, the Pavement Engineering Section sent pavement designs to the concrete and bituminous industries for their input in early stages of the road projects. When projects are candidates for alternate bidding but receive an exemption from that process, MnDOT sends the exception letters to industry representatives. In addition, the Pavement Engineering Section intervenes in projects that have similar pavement alternatives, in that it manages such projects that undergo alternate bidding (as Chapter 4 describes).

Recommended practices suggest committee membership should be broad based. The Office of Materials' Pavement Engineering Section has staff in design and materials but does not include staff involved with construction and maintenance.

3 Life-Cycle Cost Analyses

A life-cycle cost analysis is an economic tool for comparing pavement alternatives' initial and future costs.

As Chapter 2 describes, one of the practices recommended for selecting pavement type in road rehabilitation projects is to analyze the life-cycle costs of pavement alternatives. Chapter 3 discusses this practice and examines Minnesota Department of Transportation (MnDOT) life-cycle cost analyses.

We start by defining life-cycle cost analyses and describing how they are used in transportation projects in Minnesota. Next we look at recommended practices for life-cycle cost analyses. For each, we define the practice and discuss the extent to which MnDOT meets it.

DEFINING LIFE-CYCLE COST ANALYSES

As stated in Chapter 1, a life-cycle cost analysis is an economic analysis tool used to compare pavement alternatives for a given road project by evaluating their initial and expected future costs. It converts future costs to present-day values and identifies the lowest cost pavement alternative by conveying each alternative's full cost over a specific period of time.

Life-Cycle Cost Analyses for Rehabilitation Projects

Minnesota law requires MnDOT to conduct life-cycle cost analyses for road rehabilitation projects.

A 2008 Minnesota law requires MnDOT to perform a life-cycle cost analysis for road rehabilitation projects constructed as of July 2011.[1] The law requires the analysis for projects specifically classified as reconditioning, resurfacing, or road repair; MnDOT's policy clarifies that preventive maintenance projects are excluded. MnDOT policy also excludes projects that are less than two miles in length or add less than two inches of pavement. Exhibit 3.1 lists Minnesota's statutory requirements for life-cycle cost analyses, as well as the basic requirements MnDOT districts are required to follow in conducting such analyses.

Prior to the law, a December 11, 2007, MnDOT policy required districts to prepare life-cycle cost analyses for rehabilitation projects. However, even as far back as 1999, MnDOT required its districts to complete a life-cycle cost analysis in conjunction with each materials recommendation design report; up until 2002, MnDOT's Office of Materials and Road Research signed off on these analyses. After 2002, however, life-cycle cost analyses became optional and were performed at districts' discretion, which remained the case until the release of a December 2007 central office memorandum requiring such analyses for all road preservation projects.

[1] *Laws of Minnesota* 2008, article 1, section 71.

MnDOT is required to document the lowest life-cycle costs among pavement alternatives considered for a rehabilitation project.

Exhibit 3.1: Legal and Policy Requirements for Minnesota Department of Transportation (MnDOT) Life-Cycle Cost Analyses of Road Rehabilitation Projects

Legal Requirements[a]

- All pavement rehabilitation projects constructed after July 1, 2011, must undergo a life-cycle cost analysis[b]
- Each life-cycle cost analysis must compare competing pavement materials with "equal design lives"
- Each life-cycle cost analysis must use equal analysis periods[c]
- MnDOT must document the lowest life-cycle costs and all pavement alternatives considered
- MnDOT must select the low-cost alternative or document a justification for the chosen strategy

Policy Requirements for MnDOT Districts

- Identify pavement alternatives for comparison, including at least one bituminous and one concrete alternative
- Use a minimum 35-year analysis period
- Determine initial costs of each rehabilitation activity
- Determine timing and costs of future rehabilitation and maintenance activities
- Determine the value of the pavement's remaining service life[d]
- Use a real discount rate determined by MnDOT to calculate present worth of cost estimates
- Select low-cost pavement alternative or justify an exception

[a] *Minnesota Statutes* 2013, 174.185.

[b] State statutes require the analysis for projects in the reconditioning, resurfacing, and road repair categories. MnDOT policy exempts preventive maintenance projects (placing two inches or less of pavement) and short projects (two-lane roadways less than two miles in length and multi-lane roadways less than 30,000 square yards in area).

[c] The time period over which life-cycle costs are compared.

[d] The value of the pavement's life, if any, remaining at the end of the analysis period.

SOURCES: Office of the Legislative Auditor, analysis of *Minnesota Statutes* 2013, 174.185; and Khani Sahebjam, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010.

As part of our evaluation, we reviewed 52 MnDOT rehabilitation projects and, for those required to have life-cycle cost analyses, determined whether such analyses had been completed. We drew our sample from 408 rehabilitation projects, which were let between July 1, 2008, and June 30, 2013. After dividing all road rehabilitation projects by MnDOT's eight districts, we drew a sample in each district that was proportionate to its share of total rehabilitation projects. Our sample size is too small to be able to confidently generalize our results statewide; however, our review provides valuable insights on MnDOT life-cycle cost analyses. Based on our file review, we found:

- **For most, but not all, of a sample of road rehabilitation projects, Minnesota Department of Transportation districts had completed the required life-cycle cost analyses.**

Two road projects (4 percent of our sample) lacked a required life-cycle cost analysis, while 35 projects (67 percent) had a form of the required analysis. Exhibit 3.2 displays the results. We counted one project as having a cost analysis, even though the project had changed so dramatically that the analysis no longer fit the project, and the costs had not been updated to reflect the changed project. Among the 52 projects, 14 (27 percent) were exempt from the requirement for a life-cycle cost analysis because they were less than two inches in pavement thickness or they were considered "preventive maintenance," for which state law and MnDOT technical memos do not require life-cycle cost analyses. One project in our sample had no records available, and the district materials engineer speculated that it had been merged into a different project.

Exhibit 3.2: Compliance with Requirement for a Life-Cycle Cost Analysis

Status	Number in Sample	Percentage of Total Projects in Sample
Developed a life-cycle cost analysis[a]	35	67%
Exempt from life-cycle cost analysis requirement	14	27
Did not perform required life-cycle cost analysis	2	4
No project records were found[b]	1	2
Total	52	100%

[a] One project is included as having met the life-cycle cost requirement even though it changed significantly over time, and the life-cycle cost analysis was not modified to reflect project changes. We consider it as meeting the requirement in name only.

[b] No records were found for this project. The district's materials engineer stated that the project was likely merged into a different project.

SOURCE: Office of the Legislative Auditor, file review of 52 road rehabilitation projects let between July 1, 2008, and June 30, 2013.

Components of MnDOT's Life-Cycle Cost Analyses

MnDOT districts compare at least two pavement alternatives, one of which must be concrete and the other bituminous.

MnDOT's central office sets some of the elements of the life-cycle cost analyses, while MnDOT districts set others and conduct the actual calculations. MnDOT's central office sets the policies and describes procedures for developing life-cycle cost analyses. MnDOT districts, however, select pavement alternatives for consideration, make calculations, and choose a pavement option, typically the option with the lowest life-cycle costs.

Generally speaking, districts select for comparison at least two pavement alternatives, one of which must be concrete and the other bituminous. By law,

As part of the life-cycle cost analysis, districts estimate at what pavement age they will need to undertake additional rehabilitation and accompanying maintenance.

the alternatives selected must have equal design lives.[2] In cases when the alternatives do not have the same design life, MnDOT policy requires districts to compare the "closest available design life" with both a concrete and bituminous alternative. Districts estimate initial costs for the pavement alternatives and their associated future rehabilitation and maintenance; then they calculate the present value of the rehabilitation and future rehabilitation and maintenance. Finally, they determine the pavement alternative with the lowest life-cycle costs. Exhibit 3.3 diagrams two hypothetical life-cycle cost analyses.

As part of life-cycle cost analyses, districts estimate at what pavement age they will need to undertake additional rehabilitation and accompanying maintenance. Schedules of rehabilitation and maintenance include the type and timing of the work. For example, with a 3-inch mill and overlay of bituminous pavement, a district may estimate that it is optimal to treat cracks when the pavement is at year 3, perform a chip seal when pavement is at year 7, and have a second mill and overlay when the pavement is at year 14. The time between the initial rehabilitation and the second major rehabilitation is referred to as the "service life," as Exhibit 3.4 illustrates.

RECOMMENDED PRACTICES

From our synthesis of national literature, we identified recommended practices for life-cycle cost analyses. The practices relate to the: analysis period, discount rates, inflation rates and the use of differing inflation rates for various pavement materials, estimation of agency costs, use and estimation of user costs, computation approaches, and evaluation of strategies and pavement alternatives following a life-cycle cost analysis. Exhibit 3.5 lists the recommended practices. Based on our analysis of the practices and MnDOT's process we found:

- **Overall, MnDOT follows some but not all recommended practices related to life-cycle cost analyses.**

MnDOT's process departs from recommended practices on the topics of cost estimates, calculation of user costs, and computational approach. Below we define each recommended practice and compare it against MnDOT's process.

Analysis Period

The analysis period in a life-cycle cost analysis is the common period of time over which all pavement alternatives are compared. According to national literature on life-cycle cost analyses, it is important to use an analysis period that is long enough to (1) show differences in the life-cycle costs of the pavement alternatives (both initial costs and costs of future rehabilitation and maintenance)

[2] *Minnesota Statutes* 2013, 174.185, subd. 1. (b). The term "equal design lives" is not defined in law. As discussed later in Chapter 5, the term is interpreted differently. Among the interpretations are: the number of years the pavement is designed to last until it must be replaced; the years from an initial rehabilitation until it is to be replaced, but extended by additional rehabilitation and maintenance; and the years between an initial rehabilitation and the next major rehabilitation.

Exhibit 3.3: Hypothetical Life-Cycle Cost Analyses

Example 1

Pavement Alternative: 7” Concrete

Pavement Age	Description	Cost/Mile	Present Worth
0	Initial Cost of Overlay	$360,666	$360,666
13	Reseal Joints	9,572	6,770
25	Major CPR[a]	179,611	92,272
35	Remaining Service Life	—	—
	Total		$459,708
	Annual Cost[b]		$20,468
	% of Low Cost Option		100%

Pavement Alternative: 3” Mill and 3” Overlay

Pavement Age	Description	Cost/Mile	Present Worth
0	Initial Cost of Overlay	$180,646	$180,646
3	Crack Seal	2,200	2,031
11	3” Mill, 3” Overlay	180,646	134,758
14	Crack Seal	2,200	1,515
21	3” Mill, 3” Overlay	180,646	103,240
24	Crack Seal	2,200	1,161
30	3” Mill, 3” Overlay	180,646	81,230
33	Crack Seal	2,200	913
35	Remaining Service Life	(67,742)	(26,662)
	Total		$478,832
	Annual Cost[b]		$21,319
	% of Low Cost Option		104%

Example 2

Pavement Alternative: 6” Whitetopping

Pavement Age	Description	Cost/Mile	Present Worth
0	Initial Cost of Overlay	$ 403,582	$ 403,582
12	Minor CPR[a]	32,943	24,495
20	Major CPR[a]	167,619	102,293
30	Whitetopping + Concrete Removal	495,040	236,007
35	Remaining Service Life	(330,327)	(139,064)
	Total		$627,313
	Annual Cost[b]		$27,103
	% of Low Cost Option		112%

Pavement Alternative: 3” Mill and 4.5” Overlay

Pavement Age	Description	Cost/Mile	Present Worth
0	Initial Cost of Overlay	$352,000	$352,000
3	Crack Treatment	5,000	4,643
7	Surface Treatment	20,000	16,825
15	2” Mill, 3.5” Overlay	179,434	123,893
18	Crack Treatment	5,000	3,206
22	Surface Treatment	20,000	11,617
29	2” Mill, 3.5” Overlay	179,434	87,682
32	Crack Treatment	5,000	2,269
35	Remaining Service Life	(96,618)	(40,712)
	Total		$561,424
	Annual Cost[b]		$24,257
	% of Low Cost Option		100%

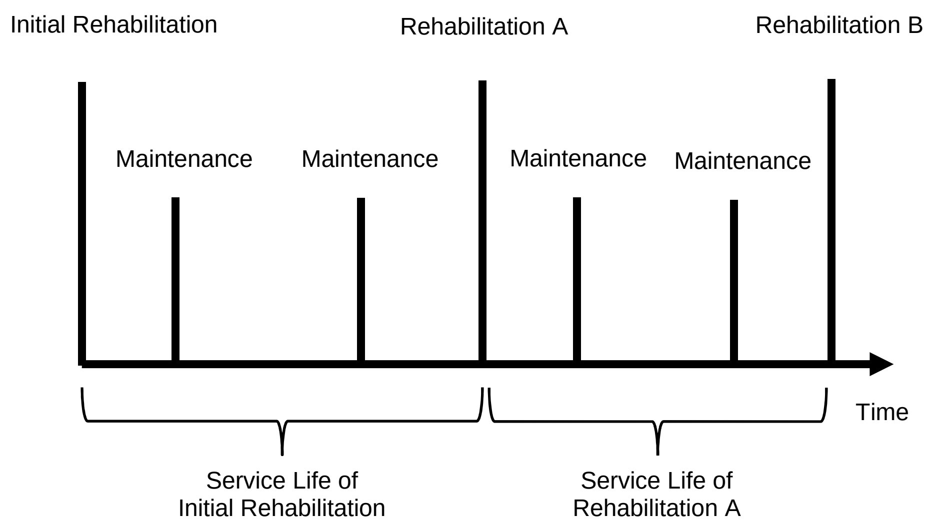
NOTES: The alternatives are based upon actual life-cycle cost analyses. Present worth of future rehabilitation and maintenance is calculated using MnDOT’s official discount rate to reflect costs in present-day values.

[a] Concrete Pavement Rehabilitation (CPR) may include techniques such as joint resealing, installing subsurface drains, and partial-depth repairs (removing faulty concrete and replacing it with high-strength concrete).

[b] Annual cost represents the yearly costs of a pavement alternative as if they occurred uniformly throughout the analysis period.

SOURCE: Office of the Legislative Auditor, analysis of life-cycle cost analysis worksheets.

Exhibit 3.4: Rehabilitation and Maintenance Scheduling



NOTE: Numbers and timing of rehabilitation and maintenance activities vary by type of pavement alternative and by road conditions, traffic volumes, and environmental factors.

SOURCES: Federal Highway Administration, *Life-Cycle Cost Analysis Primer* (Washington DC: U.S. Department of Transportation, August 2002), 12; and National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011), 16.

MnDOT requires comparisons of life-cycle costs over a minimum of a 35-year analysis period.

and (2) include one or more future major rehabilitation, such as a bituminous overlay or concrete whitetopping. The literature suggests using a minimum 30- or 35-year analysis period for rehabilitation projects.

MnDOT's policy (for projects constructed after January 28, 2010) requires that life-cycle cost analyses use at least a 35-year analysis period. A 50-year analysis period is required when projects involve placing new concrete on a new or existing base but do not include work on the subgrade.[3] From our review of a sample of projects, we found that:

- **The Minnesota Department of Transportation meets recommended practices for analysis periods in life-cycle cost analyses.**

MnDOT's minimum of a 35-year analysis period exceeds the minimum recommended amount of time. Using a sample of 40 projects with life-cycle cost

[3] The subgrade consists of soils that affect the structural design of the road but are beneath the pavement.

Exhibit 3.5: Recommended Practices for Life-Cycle Cost Analyses

	Recommended Practices
Analysis period	• Use a period long enough to show cost differences between pavement alternatives, and include at least one major rehabilitation for each alternative • Use a minimum of 30 years for rehabilitation projects
Discount rate	• Compute present value of costs using real discount rate (with inflation effects removed)[a]
Inflation rates	• Estimate costs using real dollars (with inflation effects removed)
Agency costs	• Sum the initial pavement costs and future rehabilitation and maintenance costs, and subtract the pavement's salvage value at the end of the analysis period • Base costs on historical bid data • Use timely cost information that reflects market prices at the time of construction • Include supplemental costs, such as the agency's overhead and design costs
User costs	• Estimate costs to travelers through a work zone, including those for drivers' time delay, vehicle operation costs, and possible crashes
Computation approaches	• Use an approach that accounts for the uncertainty associated with certain inputs, such as the expected pavement service life following a road treatment
Evaluation of pavement alternatives	• After a life-cycle cost analysis, evaluate jointly the economic and noneconomic factors affecting the competing pavement alternatives

[a] A discount rate converts dollars of future costs to present-day values. A "real" discount rate reflects the true time value of money with no inflation premium.

SOURCES: Office of the Legislative Auditor, analysis of National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011); Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design, In Search of Better Investment Decisions* (Washington DC: U.S. Department of Transportation, September 1998); and Federal Highway Administration, *Life-Cycle Cost Analysis Primer* (Washington DC: U.S. Department of Transportation, August 2002).

analyses, we compared each project's analysis period against MnDOT policies.[4] With one exception, all life-cycle cost analyses we reviewed met the department's standards for length of analysis periods; the exception used an 18-year analysis period for one pavement alternative and a 15-year period for a

[4] We started with a sample of 52 projects; 14 were exempt from the requirement for a life-cycle cost analysis, 2 had no such analysis, and 1 project was likely merged into a different project. Of the remaining 35 projects, 4 had separate segments, each with its own analysis of life-cycle costs; that added another 5 life-cycle cost analyses for a total of 40 such analyses that we reviewed. MnDOT's policy as of December 11, 2007, required an analysis period of at least 30 years; this changed January 28, 2010, to a minimum 35-year period.

second alternative. All used equal analysis periods to compare pavement alternatives.[5]

Discount Rates

MnDOT districts use a discount rate to convert future costs of pavement alternatives to present value.

In life-cycle cost analyses, the costs of future rehabilitation and maintenance are converted to present-day costs and then added to the initial rehabilitation costs of pavement alternatives. A discount rate is used to convert future costs to present value.[6] National literature recommends calculating present value using constant or real dollars for costs and a real discount rate. "Real" or "constant" dollars means the costs have had the effects of inflation removed. Other guidance says the discount rates should reflect historical economic trends over long periods of time and be consistent with data from the U.S. Office of Management and Budget. Furthermore, in life-cycle cost analyses, analysts should use a single discount rate to discount costs of the pavement alternatives being compared. In comparing MnDOT's process with recommended practices, we found that:

- **The discount rate calculated by the Minnesota Department of Transportation for use in life-cycle cost analyses meets recommended practices.**

MnDOT procedures prescribe how districts are to compute life-cycle costs. MnDOT's central office sets the rate districts are supposed to use to discount future costs and convert them to present day values. MnDOT calculates the discount rate by averaging the most recent five years of real interest rates on 30-year U.S. Treasury bonds. See Exhibit 3.6 for the official discount rates set by MnDOT since 2007. The five-year average produces a "smoothing" that limits the effect of one-year fluctuations. MnDOT uses a single discount rate regardless of whether the pavement alternative is bituminous or concrete.

In reviewing our sample of 40 life-cycle cost analyses, we noted errors related to discount rates. The errors included use of discount rates other than the official MnDOT discount rates as well as calculation errors. Some of the discount rate errors were small and appeared to be typos. We found that:

- **Although more than one-quarter of the life-cycle cost analyses in a sample used incorrect discount rates, and a small number had calculation errors, correcting the errors would not have changed the pavement selected.**

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[5] MnDOT required equal analysis periods as of January 28, 2010. See Khani Sahebjam, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010, p. 1.

[6] A discount rate represents the prevailing rate of interest on borrowed funds. When comparing future dollars with current dollars, economic theory holds that $100 in hand today has greater value than $100 a year from now. This so-called "time value" of money is equated with the amount of economic return that could be gained from investing $100 today. Adjusting for this value of time is known as discounting.

Exhibit 3.6: Minnesota Department of Transportation Discount Rates for Life-Cycle Cost Analyses, 2007-2014

Discount Rate	Start Date	End Date
2.2%	July 01, 2013	Current
2.5	July 01, 2012	June 30, 2013
2.7	July 01, 2011	June 30, 2012
2.84	January 15, 2010	June 30, 2011
2.9	August 14, 2009	January 14, 2010
3.1	August 13, 2008	August 13, 2009
3.2	March 20, 2007	August 12, 2008

SOURCE: Minnesota Department of Transportation, Office of Materials and Road Research.

In 22 percent of a sample of 40 life-cycle cost analyses, districts did not use the official discount rate; however, a recalculation using the correct rate showed no change in the pavement type selected.

Of the 40 life-cycle cost analyses OLA reviewed, 9 (22 percent) used discount rates that did not match MnDOT's declared discount rate.[7] Using correct discount rates is important. As stated earlier, discount rates make costs incurred at different times comparable to each other and allow direct comparisons of pavement alternatives' overall lifetime costs. Using a rate higher than the recommended discount rate yields lifetime costs that are less than what they should be; it favors alternatives that have lower initial costs and higher future costs. Using a discount rate lower than the recommended rate has the opposite effect.

We reconstructed the analysis for those life-cycle cost analyses with incorrect discount rates and substituted the official MnDOT discount rate. In no case did use of the correct discount rate change the low-cost option to the other pavement type. For most of the projects, the original differences in cost per mile were so great that use of a correct discount rate represented relatively little change. In only one case was there a small difference (2 percentage points) in costs between the pavement alternatives. Correcting the discount rate did not change the low-cost option because the correct discount rate was only one-tenth of a percentage point different from the original.

In a few life-cycle cost analyses, we observed calculation errors. In one case, the district used an inflation rate instead of a discount rate to forecast costs of future maintenance activities. In another case, a district miscalculated one pavement alternative's annual cost and the percent that cost represented of the low-cost option. In a third, the district entered the wrong amount for the initial cost of one of the three pavement alternatives.

Inflation

In life-cycle cost analyses, the values for costs of rehabilitation and maintenance may be presented in real (also called constant) dollars, meaning the values have

[7] Two additional projects dating to 2006 appeared to have incorrect discount rates, but MnDOT was unable to confirm its official discount rate for that year.

had inflation stripped away, or in current (also called nominal) dollars, meaning inflation is still reflected. National literature recommends using real dollars and real discount rates to avoid having to estimate an inflation premium for the costs and the discount rates. Further, it cautions against mixing current (or nominal) dollars with real discount rates or vice versa. In comparing recommended practices with MnDOT's process, we found that:

- **The Minnesota Department of Transportation's process for computing life-cycle costs meets the recommended practice for presenting costs in real dollars to eliminate the effects of inflation.**

MnDOT's technical memorandum on the use of life-cycle cost analyses for rehabilitation specifically counsels against using an inflation rate when computing life-cycle costs.[8] The memo explains that districts are to calculate the present value of construction and maintenance activities using a real discount rate calculated by MnDOT's central office. Our review of 40 life-cycle cost analyses showed that all but three followed MnDOT's policy. The three mistakenly used inflation rates and inflated the costs of future maintenance, when they should have been discounted.

Material-Specific Inflation

Some people have suggested adjusting estimates of future pavement costs with inflation rates that are specific to each of bituminous and concrete.

Nationwide debate is occurring over whether it is fair to assume that the future costs of bituminous pavements will grow at the same inflation rate as for concrete pavements. The U.S. Office of Management and Budget guidance on conducting life-cycle cost analyses says that analysts should use real dollar values in such analyses.[9] This means that all costs should be assumed to grow at the same inflation rate in the future and that the best indication of future prices are current prices. The reason the office takes this position is that future inflation rates are highly uncertain, and real dollar costs are especially appropriate for analyses that cover several decades.

A U.S. Office of Management and Budget review of that guidance confirms the original advice, but it goes on to say that analysts may assume different inflation rates for various materials if evidence supports such an assumption.[10] More specifically, the review says that different inflation rates may be used if there is a "reasonable basis" for expecting changes in future prices.

Nationally, the concrete industry has pointed out that inflation rates for concrete and bituminous do not match general inflation. Research produced by the concrete industry has argued that the differences between general inflation and

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[8] Khani Sahebjam, Deputy Commissioner and Chief Engineer, Minnesota Department of Transportation, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010, p. 2.

[9] U.S. Office of Management and Budget, *Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,* from: www.whitehouse.gov/omb/circulars_a094#7. A 2012 supplement concurs that use of real dollars is appropriate, especially for "long-lived projects where costs or benefits may stretch out for decades."

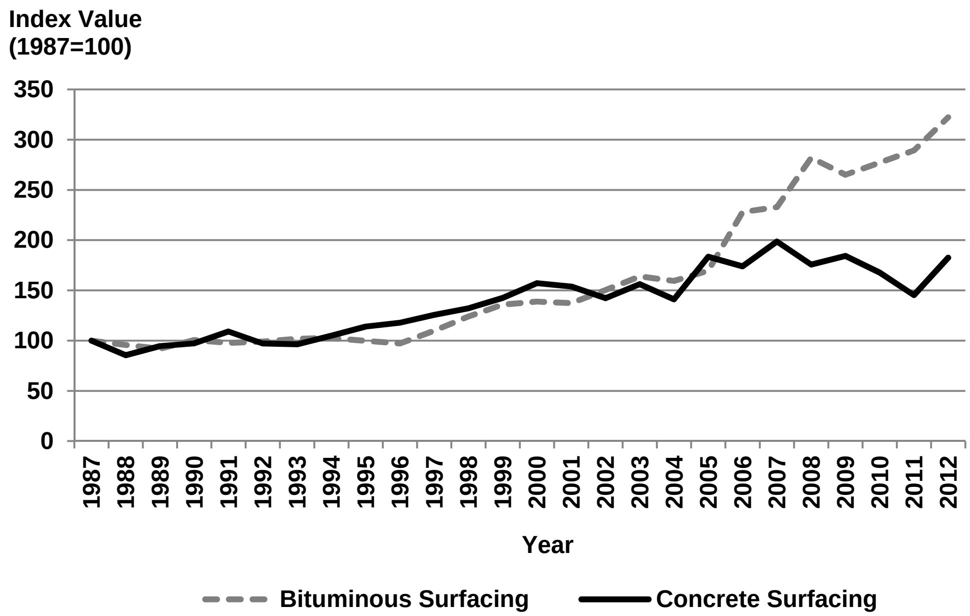
[10] U.S. Office of Management and Budget, Danny Werfe, OMB Controller, memorandum on "Interpretation of OMB Circular 94," September 20, 2012.

inflation for the two pavement materials should be reflected in life-cycle cost analyses. Minnesota's concrete industry has suggested that MnDOT's life-cycle cost analyses should recognize the higher inflation rates of bituminous. Depending on the time horizon used, such an approach could benefit concrete, because bituminous inflation has outpaced inflation for concrete in recent years.

It is difficult to predict whether future bituminous inflation rates will look like the last nine years or instead like the lower rates in prior periods.

However, our analysis of price changes in Minnesota indicates that from 1987 through 2005, average bituminous prices increased at about the same rate as average concrete prices, while average bituminous prices increased at a far greater rate from 2006 through 2012. Exhibit 3.7 shows the trends. The most recent trend in materials prices has not occurred consistently in the past, as the period from the mid-1980s to mid-2000s illustrates. It is unclear whether future bituminous inflation rates will look like the higher rates experienced over the last nine years or will resemble those during other periods when they were very low.

Exhibit 3.7: Changes in Pavement Materials' Prices as Measured from a 1987 Base of 100, 1987-2012



NOTES: This price index shows the movement of prices for bituminous and concrete pavements as measured from a base period in 1987 when the index is 100. It allows comparisons with the base and between the two pavement materials. Each year subsequent to 1987 shows the price relative to the base year. MnDOT's materials price data are based on winning bids for concrete and plant-mixed bituminous pavements, including the cost of material, labor, equipment, overhead, and profit. MnDOT excludes projects under $100,000 in value, design-build projects, and negotiated contract projects.

SOURCES: Office of the Legislative Auditor, analysis of Mary Lacho, Estimates Engineer, Minnesota Department of Transportation, memorandum to Addressees, *Cost Index – 2012 Fourth Quarter / Year End*, March 6, 2013; and Mary Lacho, interview by author, telephone conversation, St. Paul, Minnesota, July 25, 2013.

Other researchers, including some associated with the bituminous industry, say forecasting inflation for a specific paving material is unrealistic because of the difficulty in accurately modeling price increases. They also conclude that such forecasting is misleading because costs of labor, profit, and equipment have a far greater impact on overall costs than does the cost of materials.

As of early 2014, MnDOT was considering the use of material-specific interest rates and had conducted limited studies of how such rates might change present worth of pavement alternatives in a small number of road projects. It predicted changes in costs of bituminous based on three scenarios of inflation. One estimated the price of bituminous using a 2 percent annual increase over the analysis period (35 or 50 years); this was the least conservative inflation scenario. The second scenario used different inflation rates over time, inflating bituminous by 1.5 percent annually for the first ten years and 0.75 percent annually for the remaining years. The third scenario (and most conservative) used 1.5 percent annually for the first ten years, 0.75 percent annually for the next ten years, and 0 percent for the remaining years.

MnDOT's results showed that inflating bituminous prices for long periods affected the low-cost pavement alternative in the majority of the six projects that started with a bituminous alternative as the low-cost option.[11] Inflating bituminous prices resulted in four cases where the low-cost option switched to concrete under all three inflation scenarios. For the other two cases, the low-cost option remained bituminous under two inflation scenarios but switched to concrete under the least conservative scenario (2 percent annual increase).

The problem with forecasting inflation over 35- and 50-year time frames is that economists generally consider those periods too long of a time horizon to forecast price increases accurately. While acknowledging that difficulty, but because of MnDOT's efforts, we analyzed a set of projects from our sample to determine whether inflating bituminous costs (to reflect the material's higher rates of recent price increases) would affect the pavement alternative with the lowest costs.[12] We developed four inflation scenarios; three followed the inflation scenarios that MnDOT used (as described above); the fourth used a 1 percent inflation rate for the first 10 years, 0.5 percent for the second 10 years, and 0.25 percent for the last 15 years. The number of projects was too small to be representative, but our analysis showed that:

- **An inflation premium changed the low-cost option in rehabilitation projects where pavement alternatives' cost differences were small; however, this effect faded as cost differences increased.**

In cases where the difference in pavement alternatives' cost was 6 percentage points or less, the inflation premium was sufficient to change the low-cost option

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[11] A seventh project had a bituminous alternative as the low-cost option, but the effects of inflation had been calculated for only one of the three scenarios.

[12] Of 40 projects in our sample, only nine had (1) at least one concrete and one bituminous option and (2) differences in pavement alternatives' costs that were less than 20 percent. The 20 percent threshold is the one MnDOT uses to determine whether pavement alternatives are close enough to warrant alternate bidding.

Economics literature does not support forecasting inflation rates for long periods, such as the 35-year time horizons used in life-cycle cost analyses.

from a bituminous option to a concrete one. The effect of the inflation premium, however, diminished or was erased when cost differences were larger. In one project, the difference between pavement alternatives' costs was 16 percentage points, and applying an inflation premium to bituminous did not change the low-cost option. In another where the cost difference was 10 percentage points, the low-cost option changed in only one scenario—where the inflation premium was the largest. While the small size of our sample prevents us from generalizing our results statewide, the outcomes suggest that both the magnitude of the pavement alternatives' cost differences and the size and longevity of the inflation premium play roles.

We also examined economic literature on the nature of forecasting oil prices and inflation.[13] Studies have compared a simple no-change in price benchmark with more sophisticated forecasting techniques. In one such study, a 2011 discussion paper prepared originally for the Board of Governors of the Federal Reserve System concluded that statistical modeling and professional and government forecasts for predicting real oil prices are inferior to a no-change forecast, except in cases with short-term periods (one to six months, depending on the model used).[14] A more recent version of that study confirmed those results, indicating that forecasts of the real price of oil were less accurate than no-change forecasts beyond 18 months.[15] A second study employing different statistical modeling techniques reached similar conclusions, saying its model could forecast real oil prices more accurately than a no-change model only for short time horizons (of up to one year).[16] Another study on predicting inflation concluded that only forecasts using time horizons of less than six months could outperform simple no-change forecasts.[17] Based on our review, we found that:

- **The case for using material-specific inflation rates in calculating pavement-materials costs is weak.**

Economists are unable to predict future prices and inflation rates better than a no-change forecast, except for very short time horizons while using sophisticated economic models. Furthermore, there is no guarantee that historical trends in prices will repeat themselves. This suggests great caution in predicting

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[13] Economists have used oil prices as a proxy for bituminous prices. MnDOT's economist, for instance, points out that prices for "asphalt and oil products are expected—and were proven—to move together." See: John Wilson, MnDOT Economic Policy Analyst, memorandum to the Transportation Program Investment Committee, *Construction Inflation Projections for SFY 2015-2014*, October 25, 2013.

[14] Ron Alquist, Lutz Kilian, and Robert J. Vigfusson, "Forecasting the Price of Oil," G. Elliott and A. Timmermann (eds.), *Handbook of Economic Forecasting, 2* (Amsterdam: North-Holland, 2013), 427-507.

[15] Christiane Baumeister and Lutz Kilian, *Forecasting the Real Price of Oil in a Changing World: A Forecast Combination Approach* (November 13, 2013), presented at the 2014 Annual Meeting of the American Economic Association.

[16] Christiane Baumeister and Lutz Kilian, "Real Time Forecasts of the Real Price of Oil," *Journal of Business & Economic Statistics* 30.2 (2012): 326-336.

[17] Tilmann Gneiting and Thordis L. Thorarinsdottir, *Predicting Inflation: Professional Experts Versus No-Change Forecasts* (arXiv preprint arXiv:1010.2318, 2010).

inflationary increases for prices used in life-cycle cost analyses that estimate costs over a minimum 35-year span.

RECOMMENDATION

The Minnesota Department of Transportation should avoid calculating life-cycle costs with inflation rates that are specific to a paving material.

MnDOT should continue to use real dollar prices and real discount rates in its life-cycle cost analyses. Economics literature does not support the practice of predicting oil price increases over long time horizons. There is not reliable evidence of long-term future patterns in relative prices of materials, which the U.S. Office of Management and Budget says is necessary before an agency considers using different inflation rates for various materials.

Agency Costs

In life-cycle cost analyses, "agency" costs include the initial and future rehabilitation and maintenance, the pavement's salvage value, and supplemental costs, such as overhead.

In calculating life-cycle costs, "agency" costs include those for (1) the initial rehabilitation, (2) costs of future maintenance and rehabilitation, (3) the pavement's salvage value (its estimated value at the end of the analysis period), and (4) supplemental costs for administration, engineering, and traffic control. Exhibit 3.8 further defines agency costs. National literature recommends basing agency costs of the initial rehabilitation and future rehabilitation and maintenance on historical bid data. Further, it recommends using cost information that reflects market prices at the time of construction. Based on our review of MnDOT's process, we conclude that:

- **The Minnesota Department of Transportation's process for life-cycle cost analyses meets some but not all recommended practices for estimating agency costs.**

While MnDOT bases costs on historical bid prices, it does not always use up-to-date costs in the life-cycle cost analyses. Furthermore, districts sometimes used widely different prices for similar maintenance practices without identifying the basis for their prices. MnDOT districts calculate salvage values but not supplemental costs. We examine each of these topics in the following sections.

Outdated Cost Estimates

Some life-cycle cost analyses in our sample used outdated cost estimates. Most of the cost estimates used in the life-cycle cost analyses were under a year old at the time the project was let, but some were more than two years old. Of the 40 projects or segments of projects with unique life-cycle cost analyses, 28 (70 percent) contained cost estimates that were less than a year old when the project was let. Eight (20 percent) were between one and two years old, two (5 percent) were more than two but less than three years old, and two (5 percent) were more than three years old. MnDOT's technical memo has no standard on how old the cost estimates should be when used in life-cycle cost analyses. However, in estimating costs for future rehabilitation and maintenance, the

Exhibit 3.8: Agency Costs Recommended for Use in Life-Cycle Cost Analyses

	Definition
Initial costs	• Value of constructing the initial rehabilitation, such as a mill and overlay or whitetopping
Future costs	• Value of future rehabilitation, routine maintenance, and preventive maintenance associated with each pavement alternative
Salvage value	• Value of a pavement alternative at the end of an analysis period • Includes the "remaining service life," which is the structural life remaining at the end of an analysis period • Includes "residual" value, which is the value of a pavement material at the end of its service life, less the cost of removing and processing materials for reuse[a]
Supplemental costs	• Costs of the transportation agency's administration, engineering, and traffic control functions expected for a pavement alternative[b]

[a] Residual values are generally not large and have little effect on costs discounted over the analysis period.

[b] Supplemental costs can be ignored if they have approximately the same value for the different pavement alternatives.

SOURCES: Office of the Legislative Auditor analysis of National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011); Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design, In Search of Better Investment Decisions* (Washington DC: U.S. Department of Transportation, September 1998); and Federal Highway Administration, *Life-Cycle Cost Analysis Primer* (Washington DC: U.S. Department of Transportation, 2002).

MnDOT does not have a standard for updating cost estimates over time or when the scope of a project is substantially changed.

central office updates its estimates annually. Given changes over time in materials costs, it is conceivable that, over the span of two or more years, the low-cost option could change in those projects with small margins of cost differences between pavement alternatives.

In addition, MnDOT has no standard for updating the life-cycle cost analysis when the scope of the project is substantially changed. In one case, the scope of the project changed considerably over a six-month period but the life-cycle cost analysis was not updated to reflect the change. The district materials engineer acknowledged that the analysis was not updated but said that even though the project as finally scoped would most likely have doubled the initial cost of the low-cost option, he believed it would still have been the low-cost option. However, the analysis was not recalculated to verify this.

RECOMMENDATION

The Minnesota Department of Transportation should require districts to update cost estimates in their life-cycle cost analyses when such estimates are no longer current or no longer applicable to projects that have substantially changed.

MnDOT should determine under what circumstances districts should update cost estimates in life-cycle cost analyses.

The literature does not specify what length of time is too long between making cost estimates in a life-cycle cost analysis and using them to make pavement decisions. It says the cost estimates should reflect market prices at the time of construction while allowing time for internal review of the analysis. For more accurate cost estimates, MnDOT should determine under what circumstances cost estimates should be updated.

Differing Estimates of Costs

In life-cycle cost analyses, rehabilitation and maintenance costs and timing of the maintenance can differ. MnDOT's central office provides forms that districts may use for life-cycle costs. The form includes materials' costs and prices for rehabilitation strategies, which are updated yearly. However, MnDOT districts enter into life-cycle cost analyses their own estimates of the initial rehabilitation costs, and they determine the type and timing of future maintenance and rehabilitation.

- **It is reasonable for MnDOT districts to estimate costs and set rehabilitation schedules based on data from their own local road projects, but their estimates vary greatly, and they do not consistently make clear the basis for their estimates.**

MnDOT's technical memo states that, for estimating the costs of initial rehabilitation activities, districts should base costs on "their data and experience." Using our sample of 40 life-cycle cost analyses, we compared initial costs that districts entered, and we found:

- **MnDOT districts' estimates of costs for the same rehabilitation work vary greatly across a sample of projects.**

As an example, the range in initial costs for a 1.5-inch mill and 3-inch overlay of bituminous among 11 projects is from $120,000 per mile to $224,761 per mile, a difference of more than 85 percent. In another example, the range in initial costs for a 3-inch mill and 3-inch overlay of bituminous was also large, ranging from $82,000 to $251,000 among 8 projects, a difference of more than 200 percent. Besides estimating initial rehabilitation costs, some materials engineers told us they also estimate certain future rehabilitation and maintenance costs.

Materials engineers who base their cost estimates on their own projects said their estimates reflect their local costs, which they consider to be more realistic than those developed by MnDOT's central office. For instance, one district's materials engineer told us that his district's costs for a chip seal averaged $27,000

MnDOT's materials engineers said cost estimates could vary due to differences in drainage, traffic levels, and environmental conditions, among other things.

per mile compared with the central office's estimate of $19,000. Materials engineers told us that differences in costs and type of rehabilitation and maintenance from project to project around the state can be expected due to variations in drainage, traffic levels, type of past rehabilitation used, hauling distances for aggregate, and environmental conditions.

In only some cases did the life-cycle cost analyses we reviewed provide information on sources the district used to estimate costs. For instance, a district that entered $113,263 as the initial cost of a 3-inch mill and 3-inch overlay made it clear that the estimate was based on the district's bid prices received for similar projects in the prior year. Most of the life-cycle cost analysis reports we reviewed, though, did not contain that information.

Beyond our review of life-cycle cost analyses, we asked materials engineers about their process for estimating initial costs and examined files supplied by the eight districts demonstrating the historical data they used to estimate costs. We found that:

- **MnDOT districts base their cost estimates on historical data, but they follow somewhat different processes in making their estimates.**

For instance, one district bases recent bituminous costs on 2011 project prices that have been updated using data on oil prices and inflation rates calculated by MnDOT's central office; the prices are also adjusted as new project data become available. Another district estimates bituminous costs using bid prices, by type of bituminous, from projects in the previous year, excluding very small projects. In a third district, the materials engineer estimates costs based on projects that have been let in the previous year and have been checked against similar projects done in the district as well as against costs calculated by the district's estimator.

Differing Schedules for Future Rehabilitation and Maintenance

MnDOT districts also set their own schedules of future maintenance and rehabilitation; the schedules may be based on guidance offered by MnDOT's central office and are generally used in the districts' life-cycle cost analyses. The schedules for maintenance and rehabilitation are significant because each activity adds costs but also longevity to the pavement, both of which affect life-cycle costs.

MnDOT's technical memo says that districts should establish their maintenance and rehabilitation schedule based on their own experience, results from the pavement management analysis of road conditions, or Appendix E in MnDOT's *Pavement Design Manual*. We found that:

- **MnDOT districts' schedules for rehabilitation and maintenance vary greatly across a sample of projects.**

As described in Chapter 2, most MnDOT materials engineers in districts said because each road has different needs, it is not feasible to follow a predetermined rehabilitation and maintenance schedule. Instead, they schedule maintenance and rehabilitation based on their professional judgment in conjunction with the guidance offered in MnDOT's *Pavement Design Manual* or the alternate bid maintenance schedules developed in 2011.

In our review of a sample of life-cycle cost analyses, we noted wide ranges in the ages of pavement when maintenance and rehabilitation were scheduled. For instance, among projects in which a 1.5-inch mill and 3-inch bituminous overlay was considered, the first scheduled maintenance (crack treatment) ranged from having none at all up to a pavement age of 6 years. The second scheduled treatment (a chip seal) ranged from none at all up to a pavement age of 9 years. Similarly, the years between major rehabilitations varied. Among ten projects in which a 1.5-inch mill and 3-inch bituminous overlay was considered, the scheduled first major rehabilitation was at an average pavement age of 16 years, but ranged from 12 to 20 years. For eight projects with a 3-inch mill and 3-inch overlay, the pavement age at the time of the first scheduled major rehabilitation averaged nearly 15 years and ranged from 11 to 20 years.

RECOMMENDATION

The Minnesota Department of Transportation should require districts to justify the cost estimates and timing of rehabilitation and maintenance in their life-cycle cost analyses.

Transparency is important in districts' estimates of costs and rehabilitation and maintenance schedules.

We recognize that different cost estimates are to be expected when they reflect differences in materials and labor costs found from region to region across the state. Similarly, differences in scheduling maintenance activities are likely when they reflect differences in roads. At the same time, transparency of districts' estimates is important because of questions that have been raised about whether life-cycle cost analyses are realistic and calculated objectively. That skepticism can be fueled when sources of data are unclear. Transparency of district estimates would help make clear that analyses are based on good data, sound judgment, and provide the best value for the dollar spent on road rehabilitation.

To justify the validity of their cost estimates, districts should identify the sources of maintenance costs and schedules they used in life-cycle cost analyses. Because districts indicated they are already calculating costs based on their historical data, we do not anticipate that adding the source of their analysis to the life-cycle cost analysis would be a significant burden.

This recommendation does not contemplate that all projects would adhere to a uniform set of rehabilitation and maintenance costs or schedules. At the same time, if districts enter costs that represent significant departures from values set by MnDOT's central office, they should offer written justification of those departures. The same is true for scheduling maintenance or rehabilitation at years significantly different from an acceptable range agreed to by the department. It would be up to the department to determine what qualifies as a departure from an acceptable range. There are different ways this change could be implemented. One possibility is to require all districts to use the life-cycle cost form developed by MnDOT's central office. (Most, but not all, districts do so already.) The form could offer average prices and suitable ranges of scheduled maintenance. Districts that enter values outside the ranges would be required to explain their reasons. It would be incumbent upon MnDOT's central office to work with district personnel in developing and modifying the form so that districts understand it and its formulas and can use it effectively.

Salvage Value

Another recommended practice for calculating agency costs in life-cycle cost analyses is estimating "salvage" value, which is the expected value of a pavement alternative at the end of the analysis period. Pavement alternatives that are expected to still be in operation at that point have value that should be subtracted from the overall costs to make the alternatives comparable. Failing to calculate salvage value would be unfair for an alternative that is expected to last longer than others.

Salvage value has two components. One is the remaining service life; this is the value of the pavement's structural life remaining at the end of the 35-year period analyzed in the life-cycle cost analysis. The second is the residual value, defined as the value of the pavement at the end of the analysis period, less the cost of removing and reusing the pavement. National literature emphasizes the importance of accounting for remaining service life but suggests that residual values tend to be small and have little impact on results of life-cycle cost analyses. We found that:

- **MnDOT meets recommended practices for the calculation of pavement alternatives' remaining service life.**

It is recommended that transportation agencies calculate pavements' remaining value expected at the end of an analysis period, and MnDOT districts did this in all but 1 of a sample of 23 projects.

MnDOT's policy on computing life-cycle costs requires MnDOT districts to include in their costs any value for the remaining life of a pavement alternative at the end of the analysis period. It also instructs districts on the method they are to use to calculate the remaining service life.[18] MnDOT's method is among those recommended in the national literature. From our sample, we examined the 23 life-cycle cost analyses that districts had conducted after MnDOT's January 28, 2010, policy was in place. We found that all 23 included remaining service life, and 22 of the 23 were calculated accurately. In the one exception, the district had failed to estimate the remaining service life for pavement options where it was needed.

Supplemental Costs

A final component of calculating agency costs in life-cycle cost analyses is estimating "supplemental" costs. Supplemental costs include (1) administrative costs, such as overhead and contract administration; (2) engineering costs, such as design costs, construction engineering costs, construction supervision, and materials testing; and (3) traffic control costs. The literature recommends calculating supplemental costs for the pavement alternatives and including such

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[18] MnDOT, Technical Memorandum No. 10-04-MAT-01, *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects*, January 28, 2010, p. 2, says the remaining life value is calculated as the prorated share of the cost of the last rehabilitation over the remaining years of a pavement alternative's service life.

costs in a life-cycle cost analysis when the costs differ by the different alternatives. We found that:

- **MnDOT does not meet recommended practices for the calculation of supplemental costs.**

MnDOT's policy on life-cycle cost analyses for rehabilitation projects does not address the calculation of supplemental costs. MnDOT officials told us that the department has not previously considered estimating such costs for the life-cycle cost analyses. However, supplemental costs would likely differ if one pavement alternative has greater initial construction and future rehabilitation and maintenance costs over the analysis period than the other alternative.

RECOMMENDATION

The Minnesota Department of Transportation should assess differences in supplemental costs and, if such costs differ significantly among pavement alternatives, estimate the costs in life-cycle cost analyses.

If MnDOT determines that supplemental costs differ for different pavement alternatives, it should change its policy on life-cycle cost analyses for rehabilitation projects and require estimates of supplemental costs. Because of the potential difficulty in precisely estimating supplemental costs for each project, MnDOT should consider specifying such costs as a percentage of total pavement costs for each pavement alternative, as the literature recommends.

User Costs

It is recommended that, when possible, transportation agencies calculate drivers' time-delay costs and vehicle-operating costs attributable to work zones set up during road rehabilitation and maintenance.

User costs are drivers' time-delay costs, vehicle operating costs, vehicle crash costs, environmental costs, and discomfort costs. National literature recommends calculating only those user costs that can be reasonably estimated. These include costs incurred by the public traveling through work zones during road rehabilitation and maintenance. They are time-delay costs and vehicle operating costs.[19] Literature suggests that user costs can be significant, sometimes outweighing the "agency costs."

Agencies should estimate user costs when those costs differ among the pavement alternatives being compared. Agencies should focus on user costs in major work zones, not those for routine, reactive-type maintenance. (Such maintenance is generally infrequent, of short duration, outside of peak traffic times, and occurs in reaction to problems, such as potholes.) In comparing MnDOT's process with recommended practices for user costs, we found that:

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[19] In addition to time-delay costs and vehicle operating costs, the Federal Highway Administration recommends estimating costs for vehicle crashes associated with rehabilitation and maintenance work zones. Further, it recommends including user costs in the life-cycle cost analysis itself. By contrast, the National Cooperative Highway Research Program's *Guide for Pavement-Type Selection* focuses on costs of time delay and vehicle operation and recommends analyzing such costs independently instead of combining them with direct agency costs.

- **The Minnesota Department of Transportation lacks a formal evaluation of user costs.**

MnDOT's materials engineers said they informally consider user costs when selecting pavement types.

MnDOT's technical memorandum on life-cycle cost analysis instructs districts to not include user costs. MnDOT officials told us that a department subcommittee had previously explored the topic but concluded it would be too complicated and difficult to incorporate user costs into rehabilitation estimates. They said a big obstacle is that it would be difficult for the department to know how contractors' staging delays might affect users during different types of rehabilitation.

Even though MnDOT does not quantify user costs, in our discussions with materials engineers we learned that districts consider user costs when deciding among pavement alternatives. For example, one engineer said the district always looks at the setting of projects to understand whether and how traffic can be detoured around a work zone. He further explained that he must consider user costs because cities with large tourist draws have been unwilling to provide municipal consent for concrete projects due to the expected traffic detours. Another pavement engineer said certain roads do not allow for feasible detours; he explained that concrete alternatives would not work for roads where shoulders were too narrow for travel and 100-plus mile detours would be required.

RECOMMENDATION

The Minnesota Department of Transportation should develop a process for estimating user costs for road rehabilitation projects unless such costs are similar for competing pavement alternatives.

A consideration of user costs should be more consistent across MnDOT districts and road projects.

Literature suggests that for certain projects, such as those in high-traffic areas, competing pavement alternatives can have very different impacts on users, which justifies calculating user costs. We recommend that MnDOT focus on the time-delay costs and vehicle-operating costs that literature suggests can be estimated reasonably well and make up a large proportion of total user costs. Furthermore, we recommend estimating user costs separately from MnDOT agency costs but evaluating them amidst other factors once the life-cycle cost analysis is completed. A method for this type of evaluation is recommended in more detail at the end of this chapter.

Calculating user costs could be a significant undertaking, although software is available for such calculations, and the Federal Highway Administration has detailed guidance on calculating user costs.[20] Doing so is important for considering user costs consistently across districts and road projects. It would require MnDOT to: set policies on when and how to calculate user costs; determine which user costs are feasible to calculate; purchase the necessary software for making the calculations; train users how to make the calculations; and implement the process for individual projects.

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[20] U.S. Department of Transportation, Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design: Interim Technical Bulletin* (Washington DC: September 1998), 33-80.

MnDOT should determine which rehabilitation strategies make it necessary to estimate user costs and provide guidance on this to districts. As the literature recommends, MnDOT should focus the effort on (1) those pavement alternatives most likely to generate high user costs and (2) those projects where the competing pavement alternatives produce significant differences in user costs. It would be the department's responsibility to identify the pavement alternatives associated with high user costs. MnDOT should determine whether there are circumstances when districts should continue to consider user costs informally.

Computation Approaches

Two different computational approaches may be used in life-cycle cost analyses. One is called "deterministic," meaning each input into the analysis has a single, fixed value, usually determined from historical data or professional judgment. Although it is considered a straightforward computation, the deterministic approach is faulted for failing to deal with the uncertainty that could affect data inputs. The second approach is called "probabilistic" because it develops a statistical measure, called a probability distribution, that identifies the likelihood that a given input (or set of inputs) will actually occur. For instance, if there were uncertainty about the service life of a particular pavement alternative, the approach would calculate numerous life-cycle cost estimates, each with a different value for the service life (and each producing a different estimate of present worth for the life-cycle costs). Those estimates would be compared with competing pavement alternatives to identify the most cost-effective one.

The literature recommends use of the probabilistic approach to computing life-cycle cost analyses. It recognizes, however, that if historical data are unavailable to model a probability distribution for the uncertain inputs, then the deterministic approach is acceptable. In this case, agencies should use sensitivity analyses on inputs with great variability. Sensitivity analyses involve studying a range of possible values for a single input, such as rehabilitation costs or service lives, to determine their effects on the outcome. Each of those possible values would be used in computing a series of present values of pavement alternatives. From our review of MnDOT's process, we found that:

- **The Minnesota Department of Transportation's approach for computing life-cycle costs does not follow recommended practices.**

MnDOT does not account for the inherent uncertainties in estimates of life-cycle costs.

Currently, MnDOT uses a deterministic approach and does not use sensitivity analysis. Its life-cycle cost analyses use single, fixed values for discount rates, unit costs, pavement service lives, and timing of rehabilitations, despite the variability that may surround these values. As a result, its analyses do not recognize the inherent uncertainties in the estimates of life-cycle costs for different pavement types. According to research, failure to account for such uncertainty can lead to incorrect pavement decisions. While MnDOT's current approach may be easier to use and requires less information and analysis than a probabilistic approach, it could yield potentially misleading results.

RECOMMENDATION

The Minnesota Department of Transportation should study the feasibility of using an approach that accounts for the uncertainty of inputs used in life-cycle cost analyses.

MnDOT should study the pros and cons of undertaking the probabilistic statistical approach. Although the literature suggests the importance of using a probabilistic approach, the approach is only feasible if sufficient and reliable historical data exist. In life-cycle cost analyses, such data would be needed for at least one input, such as the service life of the competing pavement alternatives or costs or timing of rehabilitation and maintenance.

If it decides against a probabilistic approach, MnDOT should consider adding sensitivity analyses to its current deterministic approach. Sensitivity analyses offer information that could help in understanding variability in the present values of the pavement alternatives. While they add value, sensitivity analyses are said to be less useful than a probabilistic approach because they can allow only one parameter to vary at a time, instead of many parameters varying simultaneously. In addition, they do not provide information on the likelihood that a particular value for an input will actually occur.

EVALUATE PAVEMENT ALTERNATIVES

After completing the life-cycle cost analysis, the recommended practice is to fully evaluate the competing pavement alternatives using both economic and noneconomic considerations. The literature also recommends using a decision tool to weigh the economic and noneconomic factors and ensure all relevant factors are considered in the pavement decision.[21] The evaluation is important to make pavement type selections that are cost effective and fit the department's policies and funding goals. When comparing the recommended practices with MnDOT's practices, we found:

In addition to a life-cycle cost analysis, it is important to evaluate other relevant factors when comparing pavement alternatives.

- **Improvements are needed in the Minnesota Department of Transportation's evaluation of factors affecting pavement alternatives.**

MnDOT's process for selecting pavement type does not require districts to consider a comprehensive list of noneconomic factors, such as local government preferences, that affect pavement alternatives. Nor does it include a formal process for weighing both economic and noneconomic factors that affect pavement alternatives. This is explained in more detail below.

[21] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection*, (Washington DC: Transportation Research Board, 2011), 23. The Federal Highway Administration agrees with the need to reevaluate pavement alternatives after analyzing life-cycle costs, because many factors besides that analysis can influence pavement decisions. It does not, however, address the need for a decision tool to conduct the reevaluation. See Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design, In Search of Better Investment Decisions* (Washington DC: U.S. Department of Transportation, September 1998), 31.

Economic Factors

For economic considerations, the literature suggests evaluating the following components of pavement alternatives: initial costs, rehabilitation costs, maintenance costs, user costs, and life-cycle costs. Collectively, these factors are what constitute a life-cycle cost analysis, as described earlier in this chapter. However, the recommended practice is to consider these costs independent of results from a life-cycle cost analysis.

The intent is to evaluate each set of costs in view of its impact on the entire system of roads. For instance, the initial rehabilitation cost of a pavement alternative may look attractive from the point of view of the project's life-cycle costs. But when viewed in the context of the entire system of roads, the alternative may exceed the district's funding level. Furthermore, agencies should set a threshold for comparing the cost difference between two pavement alternatives. A cost difference above the threshold would mean the low-cost pavement alternative is accepted as the most economical one; below the threshold would mean the life-cycle costs are equivalent, and the agency has to use other factors to select the appropriate pavement alternative. We found that:

- **The Minnesota Department of Transportation partially meets recommended practices for considering economic factors of pavement alternatives.**

MnDOT's highway pavement management system allows districts to evaluate a set of projects and understand their impact on a district's road system given existing funding levels. It is designed to help when there is not enough money to pay for all identified cost-effective projects. The system looks at the "marginal" cost-effectiveness of pavement alternatives to help choose the combination of projects that will give the optimal cost-effectiveness across the full network of roads.

MnDOT's pavement management system is not designed to help districts understand the impact that a single project could have on a district's system of roads.

However, MnDOT officials said the pavement management system is not as useful when examining a single project to understand the impact it might have on the system as a whole. This is because a single 10-mile segment would have a relatively small impact on a road system with 1,800 or more miles of roadway. In our interviews in MnDOT districts, some materials engineers spoke of the importance of understanding systemwide impacts that a certain project might impose.

Beyond that, MnDOT has a threshold for determining which of two pavement alternatives is the economical one. MnDOT's technical memorandum on life-cycle costs for rehabilitation projects instructs districts to choose the low-cost alternative (or to justify an exception). In effect, this sets the threshold at $0, meaning that the low-cost option is always viewed as the most economical. This remains true even if the cost of a second pavement alternative is just one percentage point higher than the low-cost alternative.

As mentioned, MnDOT policy requires districts to provide supporting justification if they select an option other than the low-cost option. Our review of 38 projects with both concrete and bituminous alternatives showed that, in 84 percent of the projects, MnDOT districts chose the low-cost option. In the remaining six projects (16 percent), districts chose alternatives that were not the low-cost option, and for each, the districts justified their selections in writing. Of the six projects, three resulted in using the same pavement type as in the low-cost alternative; two switched to use of concrete instead of the lower cost bituminous; and one switched from the low-cost concrete alternative to bituminous.

Noneconomic Factors

For noneconomic considerations, the literature suggests evaluating pavement alternatives across at least 15 factors, such as continuity with adjacent pavement and roadway geometrics. Exhibit 3.9 lists the factors, although it is not an exhaustive list.

Exhibit 3.9: Noneconomic Factors to Consider when Evaluating Pavement Alternatives

Factor

Technical

- Roadway geometrics (e.g., varying lane widths, presence of vertical curves, longitudinal grades)
- Continuity of adjacent pavements and lanes
- Characteristics of subgrade soils
- Traffic during construction
- Future needs on geometric or capacity changes
- Safety considerations, such as delineating the contrast between pavement and shoulder

Other

- Availability of local materials and experience
- Conservation of materials and energy
- Local government preferences or local politics
- Stimulation of competition among paving industries and materials suppliers
- Noise issues due to work-zone construction or tire-pavement friction
- Experimental materials or design concepts
- Maintenance experience and equipment
- Industry capability to perform the required work
- Sustainability, such as through energy efficiency, emissions reduction, and resource conservation

NOTES: Weights should be assigned to each factor to set priorities among them; the factors should be analyzed in combination with economic factors, such as life-cycle costs.

SOURCES: National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011), 21-23; and Federal Highway Administration, *Life-Cycle Cost Analysis in Pavement Design, In Search of Better Investment Decisions* (Washington DC: U.S. Department of Transportation, September 1998), 31.

In comparing MnDOT's process with the need to evaluate noneconomic factors, we found that:

- **The Minnesota Department of Transportation's process for evaluating rehabilitation pavement alternatives formally assesses only some of the recommended noneconomic factors.**

The recommended noneconomic factors include road factors, such as subgrade soils, and other factors that are less technical by nature, such as local government preferences or the stimulation of competition between industries. MnDOT's process includes analyzing a comprehensive set of technical factors, but analysis of the less technical factors is vaguer.

In its *Pavement Design Manual*, MnDOT offers extensive guidance to districts on pertinent technical information to include in materials design recommendation reports for road rehabilitations, including geologic information, historical data on pavement condition, and traffic analyses. The guidance does not, however, cover nontechnical factors such as noise issues or local government preferences. Similarly, the draft "Pavement Type Selection" chapter written in 2013 for MnDOT's *Pavement Design Manual* does not include guidance on analyzing nontechnical, noneconomic factors.

MnDOT does not formally evaluate nontechnical factors, such as local government preferences, even though such factors can be significant when selecting pavement type.

In our interviews with district materials engineers, we heard about the significance of some nontechnical factors. Materials engineers described how local government preferences can influence the selection of one pavement alternative over another. They also said that the department occasionally made available special funding for purposes such as testing experimental designs, which altered their district's pavement selection. For example, one district received special funding to test a "stabilized full-depth reclamation" of a bituminous pavement in poor condition. The project allowed the district to recycle the existing bituminous pavement, stabilize it, and repave with a thinner bituminous pavement than would otherwise have been needed.

Weighing the Factors

To the extent that factors other than the life-cycle cost analysis weigh heavily on the decision of a pavement alternative, the national literature recommends documenting these other factors. It also recommends using a formal decision-making tool, such as a "screening matrix," to help evaluate the economic and noneconomic factors of the pavement alternatives in as objective a manner as possible. The purpose is to evaluate whether there are considerable differences between the pavement alternatives based on factors that have been predetermined to be relevant. A screening matrix or similar tool involves identifying the relevant factors to compare, weighting the factors, setting guidelines for deciding preferences among the factors, scoring the alternatives based on the factors, and interpreting the results. We found that:

- **The Minnesota Department of Transportation does not have a formal process used routinely to evaluate the combined economic and noneconomic factors affecting pavement alternatives.**

Instead of a process for weighing economic and noneconomic factors of pavement alternatives, MnDOT requires districts to analyze life-cycle costs as part of the analysis in each project's materials design recommendation report. MnDOT does have a process districts may use when it is important to use a pavement alternative other than the low-cost alternative. As mentioned earlier, MnDOT districts may select such an alternative if they justify the selection and receive approval from the district engineer. However, this is done on an exception basis, not as part of a formal evaluation done routinely and reported in the materials design recommendation reports.

MnDOT district representatives described how significant noneconomic factors affected certain road projects. But there is no formal MnDOT process for considering such factors or ensuring that pavement alternatives are consistently measured against them.

RECOMMENDATION

The Minnesota Department of Transportation should amend its guidance to require a formal process for districts to routinely weigh a combination of economic and relevant noneconomic factors that affect pavement alternatives.

It may not be necessary for MnDOT to issue guidance on all of the noneconomic factors recommended in the literature. The department, however, is in the best position to determine which noneconomic factors are relevant. Nor will it be necessary for districts to address each of the noneconomic factors in every rehabilitation project. For instance, projects that do not abut local government roads or boundaries may not have to consider local government preferences. However, the department's guidance should acknowledge the significance of nontechnical, noneconomic factors. It should also clarify how districts are to treat information associated with nontechnical factors. One possibility is requiring districts to include results of evaluating relevant nontechnical factors in the materials design recommendation reports.

Once MnDOT sets policies on considering noneconomic factors, it should establish a formal process for routinely weighing both economic and noneconomic factors. There are different ways of doing this. One possibility is to identify factors to compare and assign weights to them. Then the department could set preferences for each factor. It would also have to develop a way to score each factor and then interpret the results of the analysis. Finally, although the process should be used statewide for consistency purposes, MnDOT should decide to what extent, if any, variation from district to district is acceptable.

4

Alternate Bidding

As discussed in Chapter 2, one of the five recommended practices in a process for selecting pavement type is to establish policies for alternate bidding. In this chapter, we define alternate bidding and describe its use in Minnesota. We outline the nationally recommended practices for alternate bidding and analyze the extent to which the Minnesota Department of Transportation (MnDOT) uses recommended practices.

In alternate bidding, MnDOT asks for bids from both the bituminous and concrete industries, and the selected pavement type is the one associated with the winning bid.

DEFINING ALTERNATE BIDDING

Alternate bidding is a process whereby MnDOT lets projects for bidding from both the bituminous and concrete industries; it selects the winning bid, and the pavement type is the one associated with the successful bid. In traditional projects by contrast, MnDOT selects a pavement type and solicits bids for only that type of pavement.

One of the key reasons for alternate bidding is that the process allows both industries to bid on a project, which in theory increases competition and lowers costs. Another reason for the alternate bid process is that it allows a highway agency to account for volatility in prices for pavement materials. In traditional bidding, the life-cycle cost analyses are developed months or years in advance of when projects are let for bids. The pavement option selected following that analysis may no longer be the low-cost option at the time of bid if prices have changed in the meantime. In alternate bidding, the paving industries submit bids using costs that are current at the time of their bid submissions, which theoretically allows comparisons of more accurate market prices of the pavement alternatives than in traditional projects.

MNDOT'S USE OF ALTERNATE BIDDING

MnDOT used alternate bidding for rehabilitation projects most frequently in 2012 and 2013, with a few such projects let in earlier years, as Exhibit 4.1 illustrates. However,

- **Only a small proportion of road projects over the past five years went through the alternate bidding process.**

We analyzed MnDOT's alternate bid projects let between July 1, 2008, and June 30, 2013. This included all road projects including new construction, reconstruction, and rehabilitation projects. Of 484 pavement projects let over the five-year period through June 30, 2013, just 26 (6 percent) went through alternate bidding.[1] Among the 26 undergoing alternate bidding, 10 were resurfacing projects, 8 reconditioning, 6 new construction, and 2 reconstruction.

Exhibit 4.1: Alternate Bidding Projects by Minnesota Department of Transportation District, Fiscal Years 2009-2013

District	2009	2010	2011	2012	2013
1 - Duluth	-	-	-	1	1
2 - Bemidji	-	1	-	1	1
3 - Baxter	-	-	1	1	-
4 - Detroit Lakes	-	-	1	-	1
5 - Metro	-	-	-	2	2
6 - Rochester	-	-	1	-	2
7 - Mankato	-	1	-	2	4
8 - Willmar	1	-	-	2	-
Total	1	2	3	9	11

NOTES: Year indicates when the project was let for bidding. Projects include all those undergoing alternative bidding, including new construction, reconstruction, and rehabilitation projects.

SOURCE: Office of the Legislative Auditor, analysis of Minnesota Department of Transportation's Project Planning Management System data and bid tabulation abstracts.

MnDOT Policies

MnDOT requires alternate bidding under certain conditions for new construction or reconstruction projects and rehabilitation projects. For new construction or reconstruction projects, alternate bidding is required when the project is at least two miles in length or has 30,000 square yards or more in mainline area. Absent alternate bidding, a life-cycle cost analysis is used to identify the low-cost pavement alternative.

Road rehabilitation projects are candidates for alternate bidding unless they are short or propose thin pavement alternatives—less than four inches.

For rehabilitation projects, MnDOT instead requires the consideration of alternate bidding when the thickness of a proposed pavement alternative is at least four inches; the project must also be either at least two miles long or have at least 30,000 square yards of mainline area. MnDOT's most recent policy specifies that, after conducting a life-cycle cost analysis, districts may request an exception from alternate bidding if the price difference between the bituminous and concrete options on a given project is 20 percent or greater. In addition, districts may request an exception if they have evidence that competitive bids from both the bituminous and concrete industries are unlikely.

When rehabilitation projects are candidates for alternate bidding, MnDOT's Pavement Engineering Section in the Office of Materials and Road Research

[1] Our count of 484 projects includes a small number of projects that are double counted because one let project had two project numbers. (This might occur, for example, when a project crossed district boundaries.) Three of the alternate-bid projects had more than one project number. Thus, our analysis of alternate-bid projects includes 26 projects represented by 29 project numbers.

plays a larger role than it otherwise would. First, if a district believes an eligible project is not a good candidate for alternate bidding, it must receive approval from this section for an exception. Second, for projects subject to alternate bidding, the central office thoroughly reviews the districts' life-cycle cost analyses, substituting cost estimates and rehabilitation and maintenance activities derived centrally instead of by the district. Third, the office adjusts these life-cycle cost analyses with an inflation factor (to reflect differences between general inflation and inflation in the construction industry) and a cost factor (that reflects the expected effect of technological advancements on costs of future rehabilitation and maintenance). In addition, the office adjusts incoming bids for alternate bidding projects with a "maintenance" factor (which is described later in this chapter).

Impact of Alternate Bidding

To better understand the nature of MnDOT's alternate bidding process, we reviewed projects that underwent alternate bidding in fiscal years 2009-2013. The analysis included all road projects undergoing alternate bidding, not just rehabilitation projects. We also reviewed an economic analysis of alternate bidding completed by MnDOT in early 2014. Overall we found that:

- **Thus far, the impact of alternate bidding on competition between the bituminous and concrete industries has been limited.**

About 85 percent of alternate bid projects were awarded to bituminous contractors, which is about the same proportion as for traditional projects.

As we stated earlier, only 6 percent of all road projects let over the last five years were subject to alternate bidding. Of these 26 projects, 22 (85 percent) were awarded to bituminous contractors. Only 4 projects (15 percent) were awarded to concrete contractors. This distribution parallels the proportion of bituminous to concrete projects among traditional projects.

Part of the reason that concrete contractors won few bids was the lack of bids generated by concrete contractors. Over the 26 projects, a total of 111 contractors bid on the projects, and 82 of those (74 percent) bid bituminous. In addition:

- **On more than half of the projects that underwent alternate bidding, only one industry submitted bids.**

For 13 (50 percent) of the projects, no contractor bid on the concrete alternative. For another two projects (8 percent), no contractor bid on a bituminous alternative. In another seven projects (27 percent), only one contractor bid on concrete, and none of the concrete bidders was awarded the projects.

Some materials engineers in districts across the state were frustrated because of the lack of competitive bidding. We interviewed materials engineers in MnDOT's eight districts, and several told us that, despite efforts to develop projects that attracted both concrete and bituminous industries, some or all of their alternate bidding projects received bids from only bituminous contractors. This was frustrating to certain engineers because their districts incurred extra work, such as producing two pavement design plans instead of one.

Furthermore, they worked with paving industry representatives who made suggestions on district plans, only to have the industry fail to submit bids.

Some materials engineers also told us that alternate bidding resulted in proposed pavement designs that the engineer considered unfounded or would not have chosen otherwise. For instance, we learned of a project where MnDOT provided the district with additional funds to test an alternate bid project. The extra funding paid for a choice of pavement alternatives between seven inches of concrete or "full-depth reclamation" of bituminous; this was thicker pavement and a longer-term fix than the 3-inch mill and overlay that the materials engineer said he would have otherwise used.[2] He indicated that he would have rather used the extra money on other roads in need of work in the district instead of on the alternate bid project.

A 2014 MnDOT study found that alternate bidding had neither produced savings in the unit pricing of paving materials nor expanded the number of contractors bidding on projects.

A recent MnDOT evaluation of alternate bidding concluded that the process did not lead to increased competition.[3] The January 2014 report concluded that the alternate bidding projects let between 2009 and 2013 do "not offer a strong recommendation for continuation/expansion of MnDOT's alternate bid program, strictly on the basis of economic principles."[4] The study found that alternate bidding has neither produced savings in the unit pricing of paving materials nor expanded the number of contractors bidding on road projects. In comparing bid amounts in the awarded bid to MnDOT's own estimate of a project's costs (known as the engineer's estimate), the study found little difference between alternate bid projects and traditional road projects, indicating no apparent savings in alternate bidding projects' bid amounts. The study did show a reduction in final payments to contractors for projects with *bituminous* pavements. However, it noted this finding as "counterintuitive" and could not discern whether the result was due to the alternate bid procurement process or to other factors. It could not confirm a similar savings in total billings for *concrete* projects due to the small number of projects awarded to concrete contractors. The study did not analyze other considerations, such as engineering factors or internal department costs of using alternate bidding.

RECOMMENDED PRACTICES

Our review of national literature identifies ten recommended practices for alternate bidding.[5] The ten are: (1) identify a broad range of potential pavement alternatives; (2) develop criteria to identify feasible pavement alternatives at the project level; (3) develop suitability criteria on when to use alternate bidding; (4) establish rehabilitation and maintenance strategies for each pavement

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[2] Full-depth reclamation refers to a process of crushing the bituminous and some of the underlying base and subbase and then blending the layers to form a stable base.

[3] John L. Wilson, MnDOT Economic Policy Analyst, memorandum to Curt Turgeon, State Pavement Engineer, *Alternate Bid Economic Analysis*, January 17, 2014.

[4] *Ibid.*, 1.

[5] The practices come primarily from two sources: National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011); and Federal Highway Administration, *Technical Advisory, Use of Alternate Bidding for Pavement Type Selection*, December 20, 2012.

alternative; (5) set guidelines for conducting life-cycle cost analyses; (6) develop guidelines for achieving equivalence between pavement alternatives; (7) establish criteria for determining a "bid adjustment" factor; (8) use unbiased project specifications; (9) involve industry; and (10) implement the alternate bidding procedure, including a periodic review of the process. Exhibit 4.2 displays the practices. The first two steps were examined in Chapter 2 and are not discussed in this chapter.

Exhibit 4.2: Recommended Practices for an Alternate Bidding Process

- Identify a broad range of potential pavement alternatives
- Develop criteria to identify feasible pavement alternatives at the project level
- Develop suitability criteria on when to use the process
- Develop rehabilitation and maintenance strategies for each pavement alternative
- Set guidelines for conducting life-cycle cost analyses
- Develop guidelines for achieving equivalency of pavement alternatives
- Establish criteria for determining a factor to adjust bids
- Use unbiased project specifications
- Involve industry in developing and reviewing the alternate bidding process
- Implement alternate bidding, including a periodic review of the process

SOURCES: Office of the Legislative Auditor, analysis of National Cooperative Highway Research Program, *Report 703 Guide for Pavement-Type Selection* (Washington DC: Transportation Research Board, 2011); and Federal Highway Administration, *Technical Advisory, Use of Alternate Bidding for Pavement Type Selection,* December 20, 2012.

Based on our analysis of the practices and MnDOT's process, we found:

- **Overall, the Minnesota Department of Transportation meets most but not all recommended practices for alternate bidding.**

In the sections that follow, we define each recommended practice and compare MnDOT's process with it.

Suitability Criteria for Alternate Bidding

Not all road projects are suitable for alternate bidding.

A key practice in the alternate bidding process is establishing criteria for when the process will be used to select the type of pavement for road projects, and the National Cooperative Highway Research Program offers the following guidance.[6] Factors that could affect suitability for alternate bidding are the type, size, and scope of projects; market trends of commodity prices; and the competitiveness of the pavement alternatives. Alternate bidding is not suitable for all projects but is particularly appropriate under these circumstances: (1) there is no clear preference among pavement alternatives; (2) commodity prices at the time a project is let do not reflect historical materials costs; (3) the cost items affected by alternate bids are likely to influence the low bid; or (4) historical price data are not available for one or more of the pavement alternatives. Agencies should consider these circumstances but develop their own criteria for applying alternate

[6] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection,* 27.

bidding. In comparing MnDOT's policy with this recommended practice, we found that:

- **The Minnesota Department of Transportation meets recommended practices by having policies on the suitability of alternate bidding, although the policies had inconsistencies until early 2014.**

MnDOT has issued multiple forms of written guidance regarding alternate bidding since the department first started using it for rehabilitation projects in 2009; recent guidance was inconsistent with earlier guidance until it was clarified in January 2014. Direction written September 1, 2011, says alternate bidding shall be considered for all rehabilitation projects where the proposed pavement thickness is at least four inches and up to seven inches. During the last half of 2013, this conflicted with a criterion written in MnDOT's "Pavement Type Selection," a draft chapter of its *Pavement Design Manual*. The draft document says projects will be developed for alternate bidding if the present worth of the bituminous and concrete alternatives is within 20 percent of each other. MnDOT officials were using this criterion even though it was not part of official department policy. In our interviews, some district materials engineers described problems with the lack of definitive guidance on alternate bidding. However, MnDOT officials issued a memorandum in January 2014 that clarified the policy on suitability criteria.[7]

Development of Rehabilitation and Maintenance Strategies

Another recommended practice for alternate bidding is developing strategies for different pavement alternatives, along with their rehabilitation and maintenance activities likely needed in the future.[8] This includes the timing and extent of future rehabilitation and maintenance. The literature suggests analyzing historical project data to develop the strategies over the full life cycle of each pavement alternative. Further, it suggests avoiding reliance on expert opinion, which is subject to biases, except when reliable historical pavement data are unavailable. In comparing MnDOT with model practices, we found:

- **The Minnesota Department of Transportation developed rehabilitation and maintenance schedules for alternate bid projects and follows those same schedules regardless of the projects' location.**

MnDOT uses a uniform schedule of future rehabilitation and maintenance when estimating life-cycle costs in alternate bidding projects.

MnDOT developed schedules of rehabilitation and maintenance activities specifically for projects undergoing alternate bidding. For each concrete and bituminous rehabilitation strategy, MnDOT's schedules contain the expected rehabilitation and maintenance activities at different pavement ages, based on statewide average data. MnDOT's practice is to follow these prescribed schedules when calculating the life-cycle costs of pavement alternatives for all

[7] Tim Andersen, MnDOT Pavement Design Engineer, memorandum to Material/Soil Engineers, *New PCC Design Software to be Used for Projects that Qualify for the Alternate Bid Process,* January 21, 2014.

[8] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection,* 28.

projects undergoing alternate bidding. MnDOT officials said this is important to avoid charges of bias that could occur if each MnDOT district were to follow its own rehabilitation and maintenance schedule. However, they added that the schedules MnDOT now uses may need updating.

During interviews in MnDOT districts, several materials engineers said the schedules set by MnDOT's central office do not always match their experience within the district. They said they see differences in both the type and timing of future rehabilitation and maintenance.

MnDOT's uniform schedule is based on statewide averages and often does not match the type and timing of actual rehabilitation and maintenance in the districts.

RECOMMENDATION

The Minnesota Department of Transportation should continue to develop schedules of rehabilitation and maintenance for alternate bid projects, but the schedules should reflect local road conditions.

MnDOT should not assume that one schedule of rehabilitation and maintenance activities is appropriate for all roads across the state. The timing of future rehab and maintenance may vary for roads depending on factors such as pavement condition and climate. MnDOT should continue to set such schedules centrally but allow variances when local road conditions and historical construction and condition data warrant changes to the central schedule. MnDOT should analyze variation in the scheduled timing of rehabilitation and maintenance activities and determine when a district's departure from the central schedules is reasonable. MnDOT's central office should retain final authority for determining when varying from the central schedule of rehabilitation and maintenance is reasonable. Allowing variances from the central schedule when road condition data justifies them ensures that rehabilitation and maintenance schedules are appropriate for the circumstances within a district.

Guidelines for Life-Cycle Cost Analyses

Developing appropriate guidelines for life-cycle cost analyses is another recommended practice for alternate bidding.[9] Recommended practices for life-cycle cost analyses were discussed in Chapter 3 and will not be repeated here. However, in one important respect, MnDOT's practices for alternate bid projects differ from those in traditional projects. MnDOT calculates rehabilitation and maintenance costs based on statewide averages and inserts them into life-cycle cost analyses for alternate bid projects. In effect, MnDOT replaces a district's cost estimates with estimates calculated centrally. MnDOT officials said this is done because pavement industries had charged that districts were developing their life-cycle cost analyses in ways that predetermined their outcomes. As recommended in the literature, MnDOT uses historical bid data to calculate "agency" costs (costs of the future rehabilitation and maintenance activities over the life of the pavement). However, we found that:

[9] *Ibid.*

- **In calculating life-cycle costs for alternate bid projects, the Minnesota Department of Transportation applies statewide average prices to all alternate bid projects regardless of their location.**

While MnDOT correctly bases its estimates of rehabilitation and maintenance costs on historic bid prices, it uses these statewide averages on all alternate bid projects around the state even though they may not accurately reflect costs in a particular district. Some MnDOT materials engineers reported that the rehabilitation and maintenance costs in their districts differed from statewide averages, sometimes significantly. While it is important for the department to avoid the appearance of bias in calculating agency costs, its current approach sacrifices accuracy for uniformity.

RECOMMENDATION

In life-cycle cost analyses for alternate bid projects, the Minnesota Department of Transportation should continue to develop cost estimates centrally, but the estimates should reflect regional prices when such prices better represent actual market conditions.

In using statewide average prices to estimate costs for alternate bidding projects, MnDOT sacrifices accuracy for uniformity.

MnDOT should analyze variation in rehabilitation and maintenance cost differences around the state, in addition to calculating statewide average bid prices. This will add work to MnDOT's development of cost estimates. MnDOT should set a threshold for determining when the statewide average is substantially different enough from a district average to warrant modification. When statewide average costs do not reflect local historical price data in a district, the central office should modify them to better reflect current market prices in that district.

MnDOT's draft "Pavement Type Selection" chapter for its *Pavement Design Manual* makes it appear likely that the department will continue to use standard rehabilitation and maintenance schedules and calculate centrally the rehabilitation and maintenance costs used in analyzing life-cycle costs for alternate bid projects. MnDOT officials said it is important to do this to ensure that pavement alternatives in alternate bid projects are viewed as reliable and untainted by possible district preferences. However, modifying statewide averages when warranted by reliable district data could avoid the perception of bias while still ensuring that cost estimates are appropriate for a district's circumstances.

Guidelines for Equivalent Pavement Alternatives

When using alternate bidding, it is important to ensure that the pavement alternatives being considered are roughly equivalent.[10] Equivalence means that

[10] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection,* 28; and Federal Highway Administration, *Technical Advisory: Use of Alternate Bidding for Pavement Type Selection,* 2.

the alternatives should perform equally and provide the same level of service over the same time period. In addition, the alternatives should have roughly the same life-cycle costs.

To establish equivalency in life-cycle costs, highway agencies are encouraged to establish a ceiling of up to 20 percent of the difference in total life-cycle costs between the pavement alternatives.[11] Projects with cost differences below that ceiling would be considered equivalent and suitable for alternate bidding. We found that:

- **Minnesota Department of Transportation guidance for alternate bidding meets the recommended practice for ensuring equivalence between pavement alternatives.**

As mentioned earlier, MnDOT's January 2014 guidance specifies that rehabilitation projects with proposed pavement thickness of four or more inches and of at least two miles in length or 30,000 square yards in mainline area are candidates for alternate bidding unless districts request an exception based on cost differences. When there is a 20 percent or greater difference in total life-cycle costs, an exception from alternate bidding is permissible.

Criteria for a Bid Adjustment Factor

As recommended, MnDOT adjusts bids made on alternate bid projects because bidding is on the initial project only, not future rehabilitation and maintenance.

Setting appropriate criteria for determining a bid adjustment factor is another recommended practice.[12] Pavement alternatives may differ greatly in the cost of future rehabilitation and maintenance expected to be needed during the life-cycle period after the initial pavement project. However, bids solicited during the alternate bidding process will be for the costs of the initial project only. An adjustment to the bids is needed to reflect future cost differences so that the alternatives can be evaluated on a level playing field. The bid adjustment factor should be set in advance of soliciting bids. We found that:

- **The Minnesota Department of Transportation meets the recommended practice on setting criteria for a factor to adjust bids in alternate bidding projects, but it does not describe the adjustment in its official guidance.**

MnDOT calculates what it calls a "maintenance factor" by calculating the present worth of future rehabilitation and maintenance costs for each alternative. The lower value is subtracted from the higher one. Then, the difference, or maintenance factor, is added to the bids made on the alternative with higher future costs. MnDOT then identifies the winning bidder, whose bid on the project (when combined with the maintenance factor, if relevant) is the lowest.

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[11] The Federal Highway Administration's technical advisory suggests that life-cycle costs would be considered similar for alternate bidding when a high-cost alternative is less than 10 percent higher than the low-cost alternative.

[12] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection,* 28; and Federal Highway Administration, *Technical Advisory: Use of Alternate Bidding for Pavement Type Selection,* 3.

The maintenance factor adjustment is not made explicit in MnDOT's current written guidance on alternate bidding. In the draft "Pavement Type Selection" chapter of its *Pavement Design Manual*, MnDOT describes the maintenance factor and how MnDOT calculates it. However, this document remains a draft, and the adjustment is not explained in MnDOT's technical memorandum or other guidance on alternate bidding. In our interviews with materials engineers, we heard of difficulties some have trying to operate without clear guidance from MnDOT's central office.

RECOMMENDATION

For rehabilitation projects undergoing alternate bidding, the Minnesota Department of Transportation should explain in its official guidance the maintenance factor it uses to adjust bids.

Although MnDOT has followed the recommended practice by establishing criteria for setting a bid-adjustment factor, it should use official guidance to describe the criteria and how it uses the factor to adjust bids. MnDOT's central office needs to make its practices known to MnDOT district personnel and others. Lacking formal written guidance can result in confusion and inefficiencies. Because the adjustment practices are already in place, the cost of making the guidance explicit would be minimal.

MnDOT also uses a "cost adjustment factor" to adjust the costs of future rehabilitation and maintenance in projects undergoing alternate bidding. (This is separate from the maintenance factor described above used to adjust bids.) MnDOT makes the cost adjustment because future rehabilitation and maintenance costs are based on historical projects, and the department wants to reflect how maintenance costs may be lower in the future given expected improvements and technological advancements. We found that:

- **The Minnesota Department of Transportation adjusts the costs of future rehabilitation and maintenance with a factor that is not a recommended practice and is neither sufficiently based on data nor described in MnDOT's official guidance.**

MnDOT adjusts costs of future rehabilitation and maintenance with an inflation factor, but forecasting inflation over the long-term future is not recommended.

MnDOT uses a cost adjustment factor of 10 percent, expecting that the cost of future rehabilitation and maintenance will be 10 percent less due to improvements in designs and materials. MnDOT multiplies the cost adjustment factor by the present worth of each pavement alternative's expected future rehabilitation and maintenance. However, national literature on alternate bidding does not recommend such a factor. Furthermore, MnDOT did not base its cost adjustment factor on analysis of actual changes in costs due to technological improvements in Minnesota. The value comes, not from data, but from discussions with industry representatives leading to an expectation that better materials, practices, and equipment in the future would translate into greater efficiencies.

For alternate bid projects, the Office of Materials and Road Research also adjusts the life-cycle cost analyses with an inflation factor, which reflects the difference between general inflation and inflation in the construction industry. For instance, for a 2012 project, the inflation adjustment was 1.021, meaning inflation for the construction industry ran about 2 percent higher than the general inflation rate. The inflation adjustment is described in MnDOT's draft "Pavement Type Selection" chapter but not in other written guidance on alternate bidding for rehabilitation projects. However, our concern expressed in Chapter 3 about forecasting future inflation also pertains here. Economic literature we reviewed does not support forecasting inflation into the long-term future.

RECOMMENDATION

For rehabilitation projects undergoing alternate bidding, the Minnesota Department of Transportation should discontinue adjusting costs of future rehabilitation and maintenance with a cost factor and an inflation factor.

MnDOT should use real dollar prices in estimating present worth of pavement alternatives in projects undergoing alternate bidding. In addition, it should not adjust future rehabilitation and maintenance costs with a cost factor that is based on speculation instead of historical data.

Unbiased Project Specifications

It is recommended that transportation agencies avoid adjusting prices for pavement materials even if prices change after bidding, and MnDOT follows this practice.

For alternate bidding projects, it is important to use project specifications that do not bias the process in favor of one pavement type over another.[13] The literature suggests three practices that help make each pavement alternative comparable. One is to avoid adjusting prices paid to the contractors if materials' prices have changed after the bidding process. This is important because it is difficult to give equal treatment to different pavement materials. A second is to use approaches to balance the ways materials are quantified to avoid giving an advantage to one pavement type over another—a so-called materials' quantity risk. For example, quantifying materials based on weight or mass could produce cost overruns, whereas basing materials on area is less likely to produce such results. If an agency uses different methods to quantify materials, it may produce different levels of quantity risk for the different pavement materials. A third is to avoid any potential bias in using a quality-based incentive or disincentive structure for different pavement types. Incentives should be built in through performance-related specifications in the contract. We compared MnDOT's processes with these recommended practices and found that:

- **The Minnesota Department of Transportation meets recommended practices in using unbiased project specifications in alternate bidding.**

[13] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection,* 28; and Federal Highway Administration, *Technical Advisory: Use of Alternate Bidding for Pavement Type Selection,* 3.

First, MnDOT does not adjust materials prices even if prices change after bidding. Second, MnDOT changed the approach it had used historically for measuring quantities to avoid quantifying materials for alternate bid projects in ways that provided an advantage to one of the two pavement materials. Currently, MnDOT measures quantities of bituminous by the ton and concrete by the actual cubic yard to avoid putting one type at a disadvantage during bidding.[14] Third, in its contracts for alternate bidding projects, MnDOT uses incentives that encourage high performance for both pavement types. For instance, contract language for pavement surface smoothness is the same for both pavement types in alternate bidding contracts.

Involvement of Industry

Another recommended practice for alternate bidding is that highway agencies involve the pavement industries in the process of developing and reviewing the proposed alternate bidding.[15] Based on our evaluation, we found that:

- **The Minnesota Department of Transportation has largely met the recommended practice for involving pavement industries in alternate bidding, although industry representatives and some in the department have expressed dissatisfaction with the experience.**

In January 2011, MnDOT convened a task force, including representatives of both the concrete and bituminous industries, to discuss how to best use alternate bidding in rehabilitation projects. The task force met seven times in 2011 and 2012 but not at all in 2013. Representatives of both industries wrote to MnDOT saying that, despite being members of the task force, they did not consistently feel they were "integral parts of the process." Specifically, they felt MnDOT developed rehabilitation and maintenance schedules for alternate bid projects without reflecting industry input.

More recently, central office staff told us that the task force was unlikely to meet again until after an internal evaluation of alternate bidding was completed. That evaluation was completed in January 2014, as described earlier in this chapter. MnDOT officials have now indicated that some form of the task force will likely be involved with reviewing the draft "Pavement Type Selection" chapter of the *Pavement Design Manual* (as well as this evaluation from the Office of the Legislative Auditor).

MnDOT now routinely informs pavement industry representatives when road projects undergo alternate bidding.

Beyond the task force, MnDOT has provided opportunities for industry involvement with each of the alternate bid projects expected to be let in 2013. MnDOT's Pavement Engineering Section sent these projects' pavement designs to the concrete and bituminous industries for their input, as Chapter 2 mentioned. When projects receive exceptions to alternate bidding requirements, MnDOT sends copies of the exception letters to the industry associations. In addition,

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[14] For quantifying concrete, MnDOT uses actual cubic yards that measure thickness of the material and, for some projects, square yards to measure placement of the material. MnDOT officials said both industries prefer this approach over quantifying only with square yards.

[15] National Cooperative Highway Research Program, *Guide for Pavement-Type Selection,* 29.

MnDOT provided opportunities for industry associations to comment on the draft "Pavement Type Selection" chapter. Both industries provided written comments in late summer of 2013. However, they expressed dissatisfaction that they were not included in the work leading up to the draft document or that they received no feedback on their input.

From our interviews with materials engineers, we learned of both positive and negative ramifications of industry advocacy. For instance, one district said advice from an industry representative regarding an unbonded overlay resulted in the project ultimately going more smoothly. On the other hand, as described earlier, some materials engineers voiced frustration when their district performed extra work to answer industry representatives' questions and develop multiple designs for alternate bid projects, only to find later that bids did not come in from contractors in both industries. We also heard about one project where, due to MnDOT's Office of Materials and Road Research responses to industry concerns, the district was required to modify the project's design from its original materials design recommendation report and project designs.

Periodic Review

The final recommended practice is to implement alternate bidding and periodically evaluate it to improve it for use in future projects.[16] Based on MnDOT efforts to date, we found:

- **The Minnesota Department of Transportation meets part of the recommended practice for evaluating the alternate bidding process but has not completed its review.**

Over the last few years, MnDOT has made several changes to alternate bidding in attempts to improve it. For example, to better focus alternate bidding on projects most likely to benefit, MnDOT changed its suitability criteria to require alternate bidding only for rehabilitation projects with smaller margins of cost differences (less than 20 percent) between pavement alternatives. Most recently, it completed an internal study of economic considerations of alternate bidding in Minnesota. Because the primary motivations behind alternate bidding were to achieve economic benefits, we found:

- **Results to date from the Minnesota Department of Transportation's experience with alternate bidding raise serious questions about continuing the process in its current form.**

Changes to the alternate bidding process are needed before it can be viewed as cost-effective.

As mentioned earlier, MnDOT's study found that alternate bid projects showed little or no advantage over traditional projects in terms of competition between pavement industries or bid prices. MnDOT's analysis did not consider additional costs the department may have incurred for projects undergoing alternate bidding. Our analysis confirms that changes to the process are needed to improve alternate bidding before it can be viewed as a cost-effective use of public dollars.

[16] *Ibid.*

RECOMMENDATION

The Minnesota Department of Transportation should change its alternate bidding process.

Pavement type has to be selected for rehabilitation projects; whether that is done through alternate bidding or some other process should depend on whether the processes are both fair to the pavement industries and cost-effective for taxpayers. MnDOT must decide how to change alternate bidding to increase the likelihood that the process produces its promised results. One possibility is to further narrow the suitability criteria for alternate bidding projects in ways that focus on rehabilitation projects most likely to benefit. At a minimum, this means concentrating on projects where the cost differences between competing pavement alternatives are low and where commodity prices at the time of bidding are likely to differ substantially from historical costs. Until 2014, MnDOT's design standards for concrete limited the thicknesses of concrete used in rehabilitation projects. This topic is addressed further in Chapter 5. As MnDOT gains experience with thinner concrete pavements, it is possible that their broader use will stimulate the competition that alternate bidding originally promised but appears to currently lack.

5 Other Issues

In addition to evaluating the extent to which the Minnesota Department of Transportation (MnDOT) meets recommended practices for selecting pavements, we examined other issues that affect the process. One issue concerns a provision in Minnesota law requiring MnDOT to analyze life-cycle costs for road rehabilitation projects.[1] The second is MnDOT's design standards for concrete pavement alternatives. This chapter addresses each of those topics in turn.

STATUTORY REQUIREMENT

Minnesota law requiring life-cycle cost analyses for rehabilitation projects states that the comparison of life-cycle costs must be among competing paving materials with "equal design lives."[2] However, we found that:

- **State law does not define "equal design lives," and MnDOT districts are inconsistent in how they interpret and apply the requirement.**

Although Minnesota's statute on life-cycle cost analyses requires "equal design lives," neither state law nor MnDOT policy explicitly defines the term.[3] Nor does the term have a common interpretation.

Although Minnesota law requires MnDOT to compare life-cycle costs among pavement alternatives having "equal design lives," MnDOT policy does not explicitly define the term.

While reviewing a sample of life-cycle cost analyses and interviewing materials engineers in MnDOT districts, we learned that interpretations of equal design life differ. One interpretation is the number of years until the pavement must be replaced, without considering minor maintenance for the road. For instance, some life-cycle cost analyses we reviewed listed the design life for all pavement alternatives as 35 years, which was actually the length of the analysis period. A second is the number of years that the pavement is designed to last before it must be reconstructed. A third interpretation is the number of years a pavement is designed to last before a major rehabilitation is needed.

Although MnDOT's technical memorandum on life-cycle cost analyses does not define equal design lives, it tries to operationalize the term by describing how MnDOT districts are to meet the requirement. MnDOT's memorandum says that if a pavement alternative meets the needs of a road project but does not meet MnDOT's design standards, districts may compare it with two other pavement

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[1] *Minnesota Statutes* 2013, 174.185.

[2] *Ibid.*, subd. 1 (b).

[3] In researching the legal history of Minnesota's law, we found no committee discussion of the "equal design lives" term that might have clarified legislators' intent.

alternatives—one concrete and one bituminous—with the closest available design lives.[4] In our assessment of MnDOT's policy, we found that:

- **Minnesota Department of Transportation policy allows districts to compare pavement alternatives that have different design lives.**

Projects with three or more pavement alternatives meet the policy requirement as long as just two of the alternatives have equal design lives (however one interprets the term). In our review of a sample of life-cycle cost analyses, we analyzed 19 cases that (1) contained multiple pavement alternatives but (2) had only two alternatives with equal design lives.[5] In eight of these (42 percent), the district chose a low-cost option with a design life different from the two pavement alternatives with equal design lives. In these particular cases, districts complied with MnDOT's requirement on equal design lives but only because the policy allows a third alternative without an equal design life.

By MnDOT policy, life-cycle cost analyses that compare three or more pavement alternatives meet the legal requirement for equal design lives as long as two of the alternatives are equivalent.

Most materials engineers told us that the life-cycle cost comparisons were useful when comparing thicker pavement alternatives. However, when comparing a thin bituminous overlay with a concrete alternative, materials engineers said the life-cycle costs for concrete were higher than for bituminous. This was due at least in part to costs associated with MnDOT's concrete design standards, which required at least six inches for a concrete unbonded overlay.[6]

To comply with statutes and produce equivalent designs for pavement alternatives in projects undergoing alternate bidding, MnDOT began to vary design lives for concrete. It did this in an attempt to match the shorter design lives of bituminous. MnDOT defined "design life" as the number of years expected to pass before the road accumulated a certain level of damage caused by different wheel and axle loads (known as equivalent single axle loads for rigid pavement).

MnDOT then calculated concrete thicknesses based on 15-, 20-, and 25-years of design life, instead of the customary 35-year design life it had used routinely in the past. Creating these different design lives for concrete meant MnDOT began designing thinner concrete pavements to serve cumulatively lower traffic loads. MnDOT also developed schedules of rehabilitation and maintenance to occur much earlier in the life of a thinner pavement than a thicker one.[7] Exhibit 5.1

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[4] Khani Sahebjam, Deputy Commissioner and Chief Engineer, Technical Memorandum No. 10-04-MAT-01 to Distribution [lists], *Life Cycle Cost Analysis (LCCA) of Pavement Preservation Projects,* January 28, 2010, p. 2.

[5] The requirement for equal design lives is in MnDOT's *January 28, 2010,* technical memo and did not exist before that. Therefore, we looked for equal design lives in only those cost analyses written after January 2010. Of the 23 that met this criterion, 19 cases contained more than two pavement alternatives but, in each case, only two of the alternatives had equal design lives.

[6] In its September 2011 standards, MnDOT allowed five-inch thicknesses for unbonded concrete overlays on a case-by-case basis. Those same standards allowed a minimum five inches for concrete whitetopping (using six foot by six foot panels).

[7] Although MnDOT developed these rehabilitation and maintenance schedules for use in projects undergoing alternate bidding, some MnDOT materials engineers told us they are using those schedules as a guide for traditional rehabilitation projects as well.

Exhibit 5.1: Age of Pavement for Maintenance Treatments, by Concrete Design Life

	Age of Pavement				
Maintenance Treatment	35-Year Design Life	30-Year Design Life	25-Year Design Life	20-Year Design Life	15-Year Design Life
Resealing joints and partial depth repair	17	15	14	13	12
Minor concrete pavement rehabilitation[a]	27	25	22	—	—
Major concrete pavement rehabilitation[a]	40	35	30	25	20
Remove and replace original overlay	55	50	42	35	30

NOTES: MnDOT defines "design life" as the number of years expected before the road accumulates a certain level of damage caused by different wheel and axle loads (known as equivalent single axle loads for rigid pavement). Shorter design lives equate to thinner concrete pavements carrying smaller traffic loads and result in the need to remove and replace the pavement at earlier ages. Each maintenance treatment is expected to extend the pavement design life an additional number of years; for instance, resealing joints will extend the design life another five years. These schedules were developed for rehabilitation projects undergoing alternate bidding, whereby projects are let for bidding by both pavement industries. They are for rehabilitations including whitetopping and unbonded concrete overlays.

[a] Both minor and major concrete pavement rehabilitation encompass many of the same activities, but the extent to which repairs are needed is greater with major concrete pavement rehabilitation. For instance, either could include a "full-depth repair," which is removing and replacing the concrete and dowel bar located in a joint between concrete panels. Minor concrete rehabilitation often includes "partial-depth repairs," which means removing spalled concrete and replacing it with high-strength concrete. Major concrete pavement rehabilitation involves a significant percentage of repairs in which deterioration at a joint, crack, or panel must be removed and replaced with new concrete.

SOURCE: Minnesota Department of Transportation, "Alternate Bid PCC," October 20, 2011.

shows the different concrete designs and their maintenance and replacement schedules.[8]

In addition to the practical difficulties of implementing the requirement for equal design lives, we found that:

- **Although Minnesota law requires comparing pavement alternatives of equal design life, national literature on life-cycle cost analyses does not recommend it.**

All of our main sources of information on life-cycle cost analyses are silent on equal design lives. Computing life-cycle costs allows an agency to fairly compare different pavement alternatives as long as the alternatives are analyzed over the same period of time, costs are properly estimated, and any remaining service life at the end of that time period is accounted for.

RECOMMENDATION

The Legislature should change* Minnesota Statutes *2013, 174.185, to repeal the requirement for equal design lives in life-cycle cost analyses.

[8] MnDOT officials told us that the schedules of rehabilitation and maintenance were developed without firsthand experience on how long the thinner pavements might last and said the current schedules may not be final.

We conclude that the legal requirement for "equal design lives" is not needed.

Removing the requirement for comparing equal design lives will not change the need to analyze life-cycle costs; however, it could improve the analysis by reducing misinterpretation and the false assurance that pavement alternatives of equal design lives are now being compared. MnDOT districts will still be required to compare costs of at least one bituminous and one concrete option for each road rehabilitation project. But removing the equal design life requirement will allow them to do this more fairly and effectively. Using equal analysis periods and proper techniques for estimating costs allows for fair comparisons of pavement alternatives' economic differences.

We believe concerns that deleting the requirement will be detrimental to concrete are unfounded. In fact, as described more fully in the next section, MnDOT has quite recently made changes for concrete designs by adding new design guidance for thinner concrete overlays over bituminous than in the past.

MNDOT'S CONCRETE PAVEMENT DESIGNS

One of the issues raised by the concrete pavement industry was that MnDOT standards for designs of concrete pavement did not provide for thin concrete pavement thicknesses. Industry representatives described research at MnDOT that they believe justified the use of thin concrete overlays over asphalt for rehabilitation projects. These thin overlays, also known as thin whitetopping, are generally four to six inches thick. Ultrathin whitetopping is typically between two and four inches thick.

Whitetopping has been used to a limited extent across the country, and research has been conducted on its durability. In general, however, the research has shown that, while very promising, thin concrete overlays have had mixed results. In addition, until recently, no one had put together a design guide based on the cumulative research around the country. The purpose of a design guide would be to help highway engineers use these overlays in the right locations and design them in the most durable way.

In recognition of that need, MnDOT has been one agency in a ten-state study that has led to the development of a design guide for thin concrete overlays. Researchers at the University of Pittsburgh led the study, which was largely concluded at the end of 2013. The study resulted in a whitetopping design guide and procedures available on the Internet for highway engineers in Minnesota and elsewhere.

The research essentially shows that thin whitetopping may be used over milled bituminous that is in fair to good condition or can be brought into that condition through repair. The whitetopping requires a good bond between the existing bituminous pavement and the concrete so that the pavement moves as a single structure. The existing bituminous pavement after preparation and milling must be at least three inches thick. This does not mean that thin whitetopping can be used successfully anywhere these conditions are met. Additional variables such as climate must also be considered.

Since the release of the study, MnDOT has held a training session on the research results for its district materials engineers and soils engineers. In the training, MnDOT engineers learned about using the design guide. The program requires engineers to enter certain data, such as geographic information, condition of the existing pavement structure, and design information on the overlay and joints. Once inputs are entered, the program recommends a thickness for the concrete overlay.

In early 2014, MnDOT adopted new design guidance for using thinner concrete overlays over existing bituminous pavements.

In late January 2014, MnDOT issued new guidance on the use of the whitetopping software for projects undergoing alternate bidding. The guidance provides the steps that districts are to follow in using the software associated with the thin whitetopping design guide. It also specifies the rehabilitation schedule for the whitetopping strategy and the pavement age (20 years) at which the pavement is expected to be replaced with new concrete pavement. In addition, MnDOT officials said they plan to put information and specific directions on thin whitetopping into the draft "Pavement Type Selection" chapter of MnDOT's *Pavement Design Manual*.

It remains to be seen how soon and to what extent the new whitetopping design guide will result in MnDOT districts using thin whitetopping as a rehabilitation strategy. However, the research provides the basis for a rational concrete design based on empirical results, which MnDOT officials said had been missing previously.

Other concrete design research funded partially by MnDOT is also underway. In particular, research on unbonded concrete overlays—concrete over existing concrete—is being led by a University of Minnesota researcher. MnDOT officials expect the research to result in scientifically based design procedures for unbonded overlays but said this is likely to take another three years.

List of Recommendations

- The Minnesota Department of Transportation (MnDOT) should identify a full range of feasible pavement alternatives for road rehabilitation projects. (p. 24)

- MnDOT should avoid calculating life-cycle costs with inflation rates that are specific to a paving material. (p. 44)

- MnDOT should require districts to update cost estimates in their life-cycle cost analyses when such estimates are no longer current or no longer applicable to projects that have substantially changed. (p. 46)

- MnDOT should require districts to justify the cost estimates and timing of rehabilitation and maintenance in their life-cycle cost analyses. (p. 48)

- MnDOT should assess differences in supplemental costs and, if such costs differ significantly among pavement alternatives, estimate the costs in life-cycle cost analyses. (p. 50)

- MnDOT should develop a process for estimating user costs for road rehabilitation projects unless such costs are similar for competing pavement alternatives. (p. 51)

- MnDOT should study the feasibility of using an approach that accounts for the uncertainty of inputs used in life-cycle cost analyses. (p. 53)

- MnDOT should amend its guidance to require a formal process for districts to routinely weigh a combination of economic and relevant noneconomic factors that affect pavement alternatives. (p. 57)

- MnDOT should continue to develop schedules of rehabilitation and maintenance for alternate bid projects, but the schedules should reflect local road conditions. (p. 65)

- In life-cycle cost analyses for alternate bid projects, MnDOT should continue to develop cost estimates centrally, but the estimates should reflect regional prices when such prices better represent actual market conditions. (p. 66)

- For rehabilitation projects undergoing alternate bidding, MnDOT should explain in its official guidance the maintenance factor it uses to adjust bids. (p. 68)

- For rehabilitation projects undergoing alternate bidding, MnDOT should discontinue adjusting costs of future rehabilitation and maintenance with a cost factor and an inflation factor. (p. 69)

- MnDOT should change its alternate bidding process. (p. 72)

- The Legislature should change *Minnesota Statutes* 2013, 174.185, to repeal the requirement for equal design lives in life-cycle cost analyses. (p. 75)

Minnesota Department of Transportation
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March 12, 2014

Mr. James Nobles
Legislative Auditor
Office of the Legislative Auditor
Room 140 Centennial Building
658 Cedar Street
St. Paul, Minnesota 55155-1603

Dear Mr. Nobles:

The Minnesota Department of Transportation (MnDOT) has reviewed the evaluation report entitled "MnDOT Selection of Pavement Surface for Road Rehabilitation." As you know, this is a complicated process affected by many technical and non-technical factors. We commend your staff on their efforts. Within the last few years, the Department has been exerting a great deal of effort into establishing updated pavement type selection procedures including the use of alternate bidding, implementing findings from the MnROAD pavement test facility, establishing new pavement design methods and completely rewriting the Pavement Design Manual. Your report provides timely input regarding the completion of these endeavors.

Each competing industry provides ongoing input to local and national decision makers regarding the factors that they prefer to have considered for pavement selection. Most national guidance from the Federal Highway Administration or National Cooperative Highway Research Program tends to be very inclusive of these potential considerations. The Department will continue to focus on quantifiable economic factors and will work to include your report recommendations regarding potential improvements in this area. The use of non-economic factors is not uncommon at a program or a broader project perspective within MnDOT. However, the widespread use of noneconomic factors within a specific project element, such as pavement type selection can be difficult to quantify. The Department will continue to consider the noneconomic factors listed in Exhibit 3.9 on a programmatic and broader project perspective and look for opportunities to evaluate the formal use of non-economic factors in more detailed project elements.

The report provides input regarding adding layers of complexity with the assumption that more precision could be achieved. The current process includes assessing feasible alternatives, estimating initial costs, anticipating the timing and cost of maintenance activities over a 35-50 year period. Within these seemingly basic parameters there are a great number of differing opinions among the experts. The responsibility to understand these elements falls to the District Materials Engineer with support from the Office of Materials and Road Research. Industry input has suggested that even within the current system there are opportunities for an individual's "biases" to occur. Adding many of the suggested layers of complexity may provide opportunities to perpetuate this perception of bias. Rewriting the Pavement Design Manual will equip the Department with standardized methods and defined means to adapt the policy to local conditions.

The Department's role of pavement builder is shifting to pavement maintainer. This shift, together with the condition of the road network and the financial constraints has changed the type of projects we deploy. Efficient use of tax dollars to provide a functional pavement system is always our goal. Properly selecting the most economical pavement repair strategy for the network is a large part of achieving that goal.

The Minnesota Department of Transportation believes this has been a valuable process in identifying opportunities to improve the pavement selection process. Thank you for the work that has been done to review and evaluate a complex process.

Sincerely,

Charles A. Zelle
Commissioner

Attachment: (1)

Minnesota Department of Transportation
Response Attachment

- The Minnesota Department of Transportation should identify a full range of feasible pavement alternatives for road rehabilitation projects.

  <u>MnDOT's response</u>: The Department will provide a complete list of pavement alternatives including definitions and potential applications as part of updating the Pavement Design Manual which will be completed by late fall of 2014.

- The Minnesota Department of Transportation should avoid calculating life-cycle costs with inflation rates that are specific to a paving material.

  <u>MnDOT's response</u>: We agree that material specific inflation should not be added to pavement selection process at this time. We will continue to monitor what other agencies, the industry and academia are doing and will adjust our standards as knowledge evolves.

- The Minnesota Department of Transportation should require districts to update cost estimates in their life-cycle cost analyses when such estimates are no longer current or no longer applicable to projects that have substantially changed.

  <u>MnDOT's response</u>: The Department will establish goals for the acceptable time period between LCCA and project letting. This goal will include provisions for delays which do not impact the pavement type.

- The Minnesota Department of Transportation should require districts to justify the cost estimates and timing of rehabilitation and maintenance in their life-cycle cost analyses.

  <u>MnDOT's response</u>: As part of rewriting the Pavement Design Manual, the Department will develop standardized methods and defined means to adapt the policy to local conditions.

- The Minnesota Department of Transportation should assess differences in supplemental costs and, if such costs differ significantly among pavement alternatives, estimate the costs in life-cycle cost analysis

  <u>MnDOT's response</u>: The Department will review the administration and engineering costs for general pavement repairs to determine if the cost differences between pavement options are significant.

- The Minnesota Department of Transportation should develop a process for estimating user costs for road rehabilitation projects unless such costs are similar for competing pavement alternatives.

  <u>MnDOT's response</u>: When the majority of travelers are expected to follow the same detour route, the Department often considers user costs during project development. Quantifying detoured user costs within the Metro network is not practical because users have many rerouting choices. We do take User delay in to account when deciding to perform work between rush hours, at night or on weekends.

- The Minnesota Department of Transportation should study the feasibility of using an approach that accounts for the uncertainty of inputs used in life-cycle cost analyses.

  <u>MnDOT's response</u>: The Department will retain a consultant to assess the accuracy of recent LCCAs and determine if pursuing the use of uncertainty inputs would provide clarity to the decision process or simply create another layer of ambiguity.

- The Minnesota Department of Transportation should amend its guidance to require a formal process for districts to routinely weigh a combination of economic and relevant noneconomic factors that affect pavement alternatives.

  MnDOT's response: Noneconomic factors are often difficult to objectively quantify and justify on a project specific basis. Weighing noneconomic factors against actual economic parameters may alter the impact to real budgetary priorities. The Department will continue to consider the noneconomic factors listed in Exhibit 3.9 on a programmatic and broader project perspective.

- The Minnesota Department of Transportation should continue to develop schedules of rehabilitation and maintenance for alternate bid projects, but the schedules should reflect local road conditions.

  MnDOT's response: As part of rewriting the Pavement Design Manual, the Department will develop standardized methods and defined means to adapt the policy to local conditions while maintaining a level playing field for both industries.

- In life-cycle cost analyses for alternate bid projects, the Minnesota Department of Transportation should continue to develop cost estimates centrally, but the estimates should reflect regional prices when such prices better represent actual market conditions.

  MnDOT's response: As part of rewriting the Pavement Design Manual, the Department will develop standardized methods and defined means to adapt the policy to local conditions while maintaining a level playing field for both industries.

- For rehabilitation projects undergoing alternate bidding, MnDOT should explain in its official guidance the maintenance factor it uses to adjust bids.

  MnDOT's Response: As part of rewriting the Pavement Design Manual, the Department will define the procedure to develop the maintenance factor used in the alternate bid process.

- For rehabilitation projects undergoing alternate bidding, MnDOT should discontinue adjusting costs of future rehabilitation and maintenance with a cost factor and an inflation factor.

  MnDOT's response: These items were created as part of the 2009 Tech Memo on Pavement Type Determination as requested by both industries and an advising Economics professor from the University of Minnesota. Their continued application will be reconsidered.

- The Minnesota Department of Transportation should change its alternate bidding process.

  MnDOT's response: The Department has and will continue to refocus the alternate bidding process. The goal has always been to use actual contract prices at the time of letting to determine the low cost pavement alternative. To date, many of the projects have not generated interest from both industries. As previously mentioned, the Department plans on retaining a consultant to review the LCCA documentation versus the letting results to ascertain where and when it should be applied.

- The Legislature should change Minnesota Statutes 174.185 to repeal the requirement for equal design lives in life-cycle cost analyses.

  MnDOT's response: This is consistent with the Department's position.

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