We all have a stake in A to B

Transportation Asset Management Plan

July 2014

Draft

MinnesotaGO

A Collaborative Vision for Transportation

Executive Summary

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EXECUTIVE SUMMARY

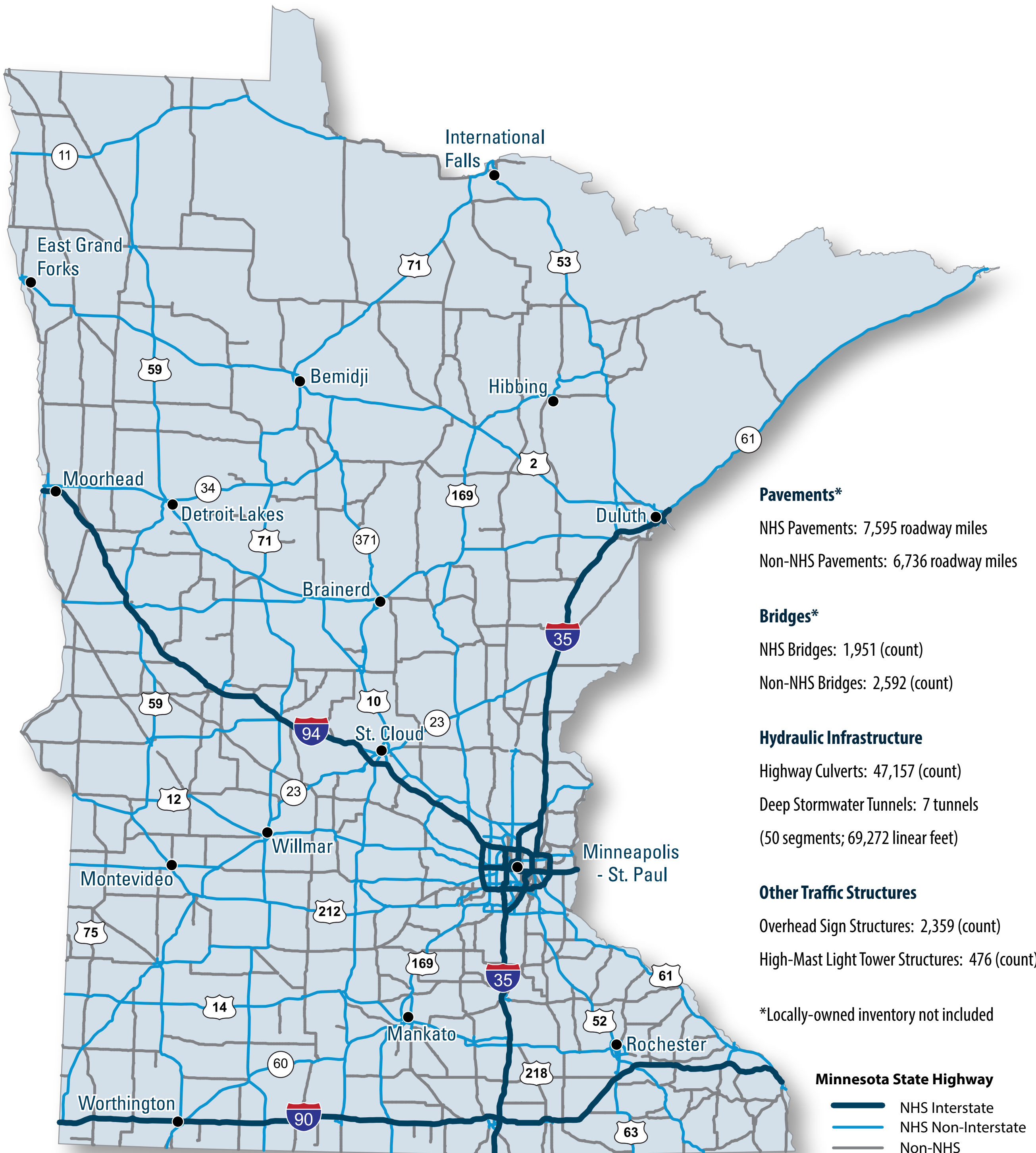
Overview

In accordance with the Moving Ahead for Progress in the 21st Century Act ("MAP-21" – the federal transportation authorization signed into law on July 6, 2012), the Minnesota Department of Transportation (MnDOT) has developed its first ever Transportation Asset Management Plan (TAMP). It was a collaborative effort, guided by a TAMP Steering Committee with representation from a wide range of MnDOT offices and districts, as well as from the agency senior leadership. MnDOT also worked closely with the Federal Highway Administration (FHWA), the FHWA Minnesota Division, and regional partners (e.g. Metropolitan Planning Organizations, Regional Development Commissions) to create this plan. As a national pilot project, MnDOT's TAMP, along with those produced by Louisiana Department of Transportation and Development and New York State Department of Transportation will serve as an example and guide for other states as they develop TAMPs of their own.

The TAMP will continue to, and in fact already has improved infrastructure management at the agency. Using the TAMP as a guide, MnDOT will more thoroughly analyze life-cycle costs, evaluate risks and develop mitigation strategies, establish asset condition performance measures and targets, and develop investment strategies. The TAMP will also serve as an accountability and communication tool and will inform established capital and operations planning efforts.

This TAMP document is accompanied by a *TAMP Technical Guide*, which provides further detail about the process, methodology analyses, and procedures used during its development. The TAMP Technical Guide has been designed to roughly parallel the main TAMP with nine sections, each of which corresponds to a specific TAMP chapter. Specific elements in the guide are referenced and hyperlinked throughout the TAMP.

Figure ES-1: Minnesota's State Highway System



Background

Minnesota's 14,000-mile state highway system – constructed, operated, managed, and maintained by MnDOT – is critical to the state's economic competitiveness and quality of life. Successful administration of such an extensive and complex system relies on sound investment strategies and management practices. To this end, MnDOT has used performance measures to inform management and investment decisions since the mid-1990s; these were made a formal part of MnDOT's statewide planning processes in 2003.

With the passage of MAP-21 each state transportation department is required to develop a risk-based TAMP for all pavements and bridges on the National Highway System (NHS). Because MnDOT had already begun to implement asset management principles prior to the MAP-21 legislation, it was in a good position to expand beyond MAP-21 requirements. This TAMP includes pavements and bridges on the entire state highway system as well as several smaller asset categories: highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures (see **Figure ES-1**). Additional asset categories will be included in future MnDOT asset management planning initiatives.

MnDOT expanded beyond the MAP-21 required assets.

ASSETS	MnDOT TAMP	MAP-21 REQUIRED
Pavement	✓	✓
Bridges	✓	✓
Highway Culverts	✓	
Deep Storm Tunnels	✓	
Overhead Signs	✓	
High-mast Lights	✓	

Performance Measures and Targets

MnDOT's performance-based approach to asset management relies on measures to assess system performance, identify needs, and develop investment priorities. Historically, these measures have included pavement ride quality and bridge condition and are used, along with targets for each measure, to develop the 20-year State Highway Investment Plan (MnSHIP). Additional performance measures, tracking things like culvert and stormwater tunnel condition, have been monitored and used internally for managing asset-specific programs, but not for establishing investment priorities.

As part of the TAMP process, MnDOT experts further developed performance measures and targets for several of these ancillary asset categories and recommended them for formal inclusion in future iterations of MnSHIP. **Figure ES-2** explains the performance measures for each asset category included in the TAMP, along with MnSHIP targets where they exist.

Figure ES-2: Performance Measures By Asset Type

ASSET TYPE	PERFORMANCE MEASURE	MNSHIP (2013) TARGET
Pavements	Share of system with lane miles with Poor ride quality	≤ 2% (NHS) ≤ 3% (Non-NHS)
Bridges	NHS bridges in Poor condition as a percent of total NHS bridge deck area	≤ 2% (NHS) ≤ 8% (Non-NHS)
Highway Culverts	Share of culverts in Poor or Very Poor condition	NA
Deep Stormwater Tunnels	Tunnels in Poor and Very Poor condition, measured as a percent of total tunnel system length	NA
Overhead Sign Structures	Share of overhead sign structures in Poor or Very Poor condition	NA
High-Mast Light Tower Structures	Share of High-Mast Light Tower Structures in Poor or Very Poor condition	NA

Notes: MnDOT uses multiple measures to evaluate the effectiveness of its pavement and bridge management activities. The measures listed here are those used to calculate MnDOT's performance-based investment needs. For a more comprehensive listing of MnDOT's pavement performance measures, see the 2013 Pavement Condition Annual Report. Additional bridge measures can be found in MnDOT's Annual Transportation Performance Report.

Asset Inventory and Condition

A considerable amount of information is needed to develop a robust TAMP. For the pavements and bridges, this information was, for the most part, readily available in MnDOT's pavement and bridge management systems. For other asset categories, data were less complete or accessible. Condition inspections are performed less consistently on deep stormwater tunnels, overhead sign structures, and high-mast light tower structures, resulting in limited maintenance histories and asset condition deterioration rates for these asset categories.

MnDOT is using the TAMP process to assess the maturity level of the maintenance and management of many of its assets, to identify process improvements that will help manage them more effectively, and to apply these principles to other MnDOT asset groups. Folios were created for each asset category to summarize inventory, estimate replacement value, and report on data collection, management technique, reporting practices, current condition, recommended targets, and planned investment levels over the next 10 years. **Figure ES-3** summarizes the system-wide replacement values for the asset categories included in the TAMP.

Figure ES-3: Replacement Cost by Asset Category

ASSET CLASS	REPLACEMENT COST
Pavements	$29.5 billion
Bridges (includes large bridges and culverts greater than 10 feet)	$6.6 billion
Hydraulic Infrastructure: Highway Culverts	$1.7 billion
Hydraulic Infrastructure: Deep Stormwater Tunnels	$300 million
Other Traffic Structures: Overhead Sign Structures	$200 million
Other Traffic Structures: High-Mast Light Tower Structures	$19 million

Risk Management

Risk – or the effect of uncertainty on objectives – can help a transportation agency more successfully plan for possible system and program disruptions and complications, mitigate potential consequences, and improve agency and infrastructure resiliency.

Even before MAP-21, risk management had been a focus area for MnDOT, implemented throughout the agency from high level investment, management, and operations plans to individual asset management programming processes. MnDOT began developing the risk section of the TAMP with an exercise designed to focus on "global" risks (e.g. natural events, operational hazards) and their effects on the assets, the public, and the agency. Discussions were held with in-house technical experts to assess the major risks related to each asset category.

Upon further deliberation, the technical experts and the project management team concluded that MnDOT's current practices were already mindful of many global risks and that the agency (and the public it serves) would benefit more if the TAMP emphasized "undermanaged risks" – areas in which there were clear opportunities for improvement at MnDOT. After pivoting to this concept and removing from the list those risks that were already well-managed by the agency, a final list of undermanaged risks and associated risk mitigation strategies was presented to the TAMP Steering Committee for prioritization. **Figure ES-4** displays the prioritized mitigation strategies, which were used to establish investment priorities and to amend existing business processes to improve the management of assets at MnDOT. **Chapter 9** of the TAMP includes a similar table (**Figure 9-2)** which also includes estimated costs, expected implementation timeframes, and individual MnDOT office responsibilities for each strategy.

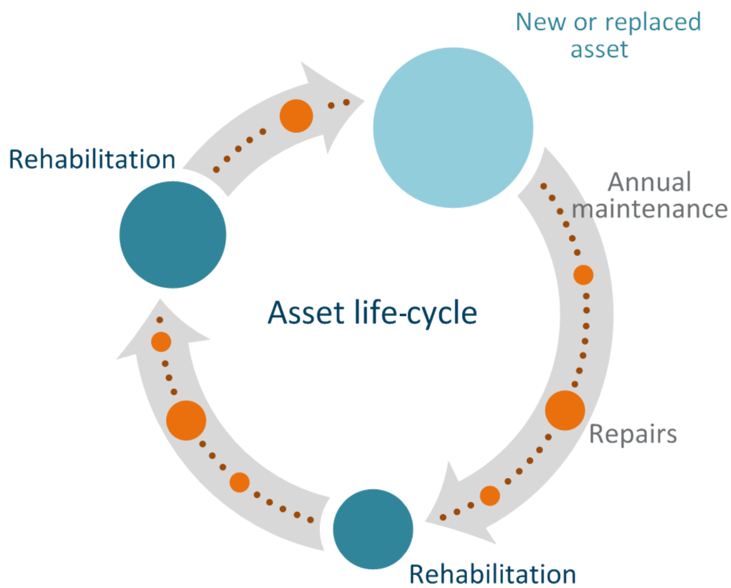
Figure ES-4: Prioritized Strategies for Mitigating Undermanaged Risks

PRIORITY LEVEL 1 STRATEGY	PURPOSE(S)
Annually track, monitor, and identify **road segments** that have been in Poor condition for more than five years and consistently consider them when programming.	To provide additional information when prioritizing projects; to highlight roads that have been in Poor condition for an extended period of time; to help MnDOT improve level of service for customers statewide
Address the repairs needed on the existing South I-35W **deep stormwater tunnel** system.	To improve condition of South I-35W deep stormwater tunnel; to alleviate safety concerns and reduce overall percentage of deep stormwater tunnel system in Poor and Very Poor condition (thereby helping MnDOT meet targets)
Investigate the likelihood and impact of **deep stormwater tunnel** system failure.	To improve understanding of the likelihood for failure of the deep stormwater tunnel system (located entirely in MnDOT's Metro District) and the likely impacts of such an event; to aid planning and management of the system
Develop a thorough methodology for monitoring **highway culvert** performance.	To increase availability of information; to develop a systematic and objective methodology to monitor culverts; to manage culverts more effectively
Develop and adequately communicate construction specifications for **overhead sign structures** and **high-mast light tower structures**.	To prevent installation problems that lead to premature deterioration and reduced asset life; to ensure that MnDOT inspectors and vendors understand and adhere to requirements (e.g. torque thresholds)
Track **overhead sign structures** and **high-mast light tower structures** in a Transportation Asset Management System (TAMS).	To more deliberately and effectively manage these asset categories; to include more assets in TAMS, thereby improving cross-asset tradeoff decision-making
PRIORITY LEVEL 2 STRATEGY	**PURPOSE(S)**
Collect and evaluate performance data on ramps, auxiliary lanes, and frontage **road pavements** for the highway system in the Twin Cities Metro Area.	To determine current inspection procedure is sufficiently capturing needs; to more effectively manage non-mainline highway pavements
Augment investment in **bridge** maintenance modules and develop related measures and tools for reporting and analysis.	To develop performance models to predict changes in bridge performance over time; to more effectively manage bridges
Include **highway culverts** in TAMS.	To more deliberately and effectively manage highway culverts; to include more assets in TAMS, thereby improving cross-asset tradeoff decision-making
Place pressure transducers in **deep stormwater tunnels** with capacity issues.	To place pressure transducers in deep stormwater tunnels that will collect better capacity-specific data such as pressure impact by water volume
Incorporate the **deep stormwater tunnel** system into the bridge inventory.	To improve regularity of deep stormwater tunnel inspections by adding the tunnel system to the bridge inventory, with inspection frequency tied to reported condition
Develop a policy requiring a five-year inspection frequency for **overhead sign structures**, as well as related inspection training programs and forms.	To establish a formal inspection program for overhead sign structures, based on MnDOT's best knowledge of structure condition, deterioration rates, and inspection needs
PRIORITY LEVEL 3 STRATEGY	**PURPOSE(S)**
Repair or replace **highway culverts** in accordance with recommendations from the TAMS (once it is implemented).	To improve overall system quality and management; to meet newly established and vetted asset targets

Life-Cycle Cost Analysis

Asset management helps to minimize the total cost of managing transportation assets in part by focusing on all phases of an asset's life-cycle (see in **Figure ES-5**). When a new road is built, the state is committing not only to the initial construction costs, but also to the future costs of maintaining and operating that road. Over a long time period, future costs can be much greater than the initial cost. Therefore, it is important to manage facilities as cost-effectively as possible over their entire lives, and to be mindful of life-cycle costs when making decisions about an asset.

Figure ES-5: Phases in a Typical Asset Life-Cycle



The life-cycle analyses conducted as part of this TAMP involved comparing several different improvement strategies for each asset type in order to determine which of the strategies was most cost-effective over an extended period. Analysis periods of various lengths were used for different asset categories based on the desire to include one full reconstruct (replacement) cycle for each asset.

At least two improvement strategies were analyzed for each asset – a "typical" strategy, which considered the types of treatments normally performed by MnDOT, and a "worst-first" strategy, which assumed limited improvements and that each asset would be allowed to deteriorate to the point that it needed to be replaced. A third strategy, referred to as the "desired" strategy, was considered for pavements only (due to a lack of data for other assets) and followed the treatment intervals suggested as ideal in MnDOT's Pavement Design Manual.

The results of the analyses are presented in **Chapter 6** of this document; **Figure ES-6** displays the results for the pavement asset category. The first chart represents the total costs of each investment strategy over the analysis period (excluding the initial capital investment). As illustrated, the worst-first strategy is significantly more expensive than the typical or desired strategy, indicating that MnDOT's typical improvement strategies are relatively cost-effective. The second chart shows future MnDOT capital and maintenance commitments for each new asset constructed (again, excluding the initial investment). Thus, for every $1.00 initially invested in a new lane-mile of pavement, MnDOT will need to plan for between $1.11 and $2.87 in additional capital and maintenance costs over the remainder of the analysis period. The total life-cycle costs vary by the investment strategy (typical, desired, worst-first).

Figure ES-6: Pavement Life-Cycle Cost Results

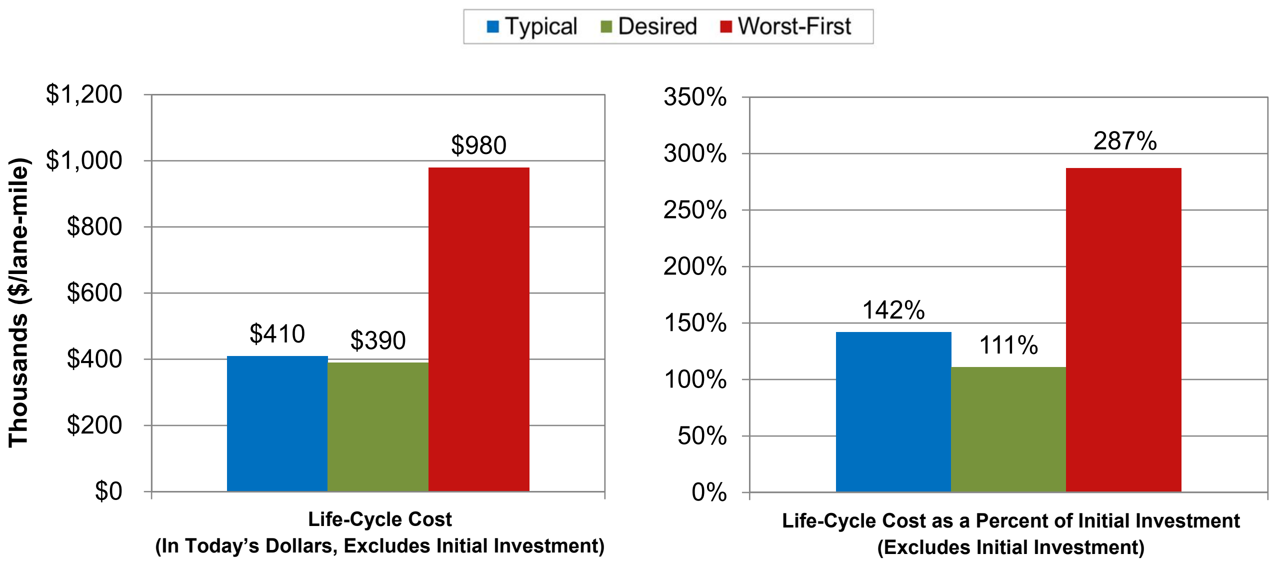


Figure ES-7 summarizes the annualized life-cycle costs for each of the asset categories included in the TAMP.

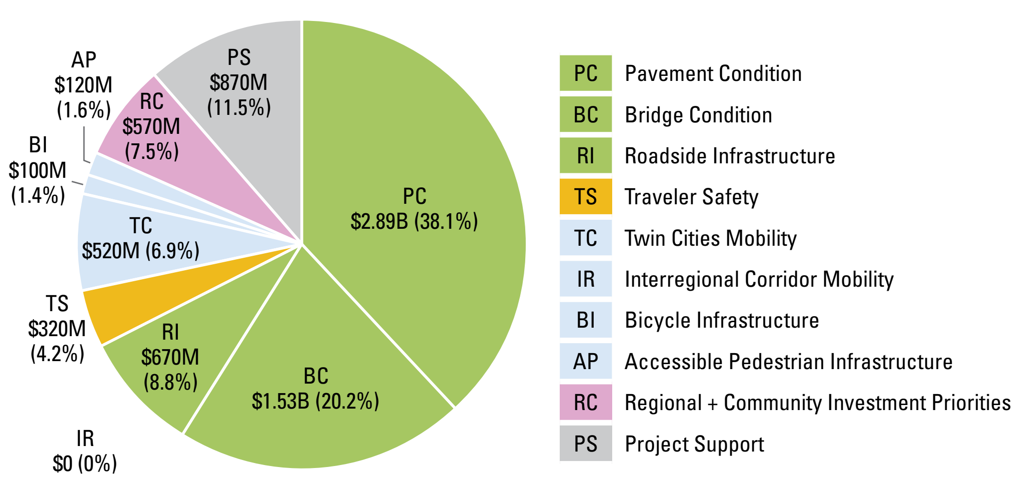
Figure ES-7: Asset Annualized Life-Cycle Costs

ASSET CLASS	ANNUALIZED COST
Pavements	$12,000 per lane-mile
Bridges: Large Bridges	$16,000 per bridge
Bridges: Culverts 10 feet or greater	$1,300 per large culvert
Hydraulic Infrastructure: Highway Culverts	$150 per small culvert
Hydraulic Infrastructure: Deep Stormwater Tunnels	$30,000 per mile of tunnel
Other Traffic Structures: Overhead Sign Structures	$900 per structure
Other Traffic Structures: High-Mast Light Tower Structures	$400 per structure

Financial Plan and Investment Strategies

When developing investment priorities, MnDOT accounts for various factors, including revenue trends, federal and state law, level-of-service provided by the system, and public input. Over the next 10 years, MnDOT's priorities – as described in it's 20-year State Highway Investment Plan (MnSHIP) and illustrated in **Figure ES-8** – will aim to balance investments that preserve existing infrastructure with investments in safety, multimodal transportation, and other projects that improve economic competitiveness and quality of life in Minnesota.

Figure ES-8: Capital Investments



Rather than replace the sound, publicly-vetted investment direction provided in MnSHIP, **Chapter 8** of the TAMP seeks to build upon and further refine the financial direction of that document. For instance, while MnSHIP groups many non-pavement and non-bridge assets together in a "Roadside Infrastructure" category (see **Figure ES-8**), the TAMP individually addresses and recommends targets for several of the constituent asset categories – highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures. These targets, and the investment levels needed to reach them, are included in **Figure ES-9**, along with the pavement and bridge targets and planned investments from MnSHIP.

Figure ES-9: Targets and Planned or Needed Investment to Achieve Targets

ASSET	CURRENT CONDITION	TARGET RECOMMENDATION	INVESTMENT*
Pavement: Interstate	2.4% Poor	≤ 2% Poor	$392 million
Pavement: Non-Interstate NHS	4.3% Poor	≤ 4% Poor	$1.13 billion
Pavement: Non-NHS	7.5% Poor	≤ 10% Poor	$1.38 billion
Pavement: Total	**NA**	**NA**	**$2.9 billion**
Bridge: NHS	4.7% Poor	≤ 2% Poor	$1.10 billion
Bridge: Non-NHS	2.1% Poor	≤ 8% Poor	$430 million
Bridge: Total	**NA**	**NA**	**$1.53 billion**
Hydraulic Infrastructure: Highway Culverts	10% Poor; 6% Very Poor	≤ 8% Poor; ≤ 3% Very Poor	$ 400 million
Hydraulic Infrastructure: Deep Stormwater Tunnels	39% Poor; 14% Very Poor	≤ 8% Poor; ≤ 3% Very Poor	$ 35 million (condition) + $1.6 million (inspection)
Other Traffic Structures: Overhead Sign Structures	6% Poor; 8% Very Poor	≤ 4% Poor; ≤ 2% Very Poor	$8 million
Other Traffic Structures: High-Mast Light Tower Structures	6% Poor; 15% Very Poor	TBD	TBD

*Pavement and bridge figures represent 10 year planned investment to meet targets; hydraulic Infrastructure and other traffic structures figures represent 10 year needed investment to meet targets.

Implementation and Future Developments

While meeting federal requirements is an important objective, MnDOT's primary reason for developing this TAMP is to improve the management of Minnesota's transportation assets, with special focus on risk and life-cycle costs. Success will be largely determined by the extent to which the principles and initiatives outlined in this document are incorporated, along with existing plans, into MnDOT's business practices.

To support this, MnDOT has established an Asset Management (governance) Steering Committee that is responsible for developing, updating, and monitoring the enhancements described in **Chapter 9** of the TAMP as well as other asset management planning initiatives. As a result of the TAMP process and other parallel asset management initiatives, several enhancements are currently underway. This includes collection of better maintenance data to improve life-cycle costs for assets included in this TAMP, initiation of a Transportation Asset Management System, programming of funds for rehabilitation of the I-35 south deep stormwater tunnel, and development of an Overhead Sign Structure inspection policy.

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Contents

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Chapter 1

INTRODUCTION

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INTRODUCTION

Overview

The 14,000-mile state highway system[1] constructed, operated, managed, and maintained by the Minnesota Department of Transportation (MnDOT) represents 74 percent of the State-owned capital assets. This transportation network is critical to Minnesota's economic competitiveness and quality of life, providing transportation connections that are necessary for thriving communities and successful businesses. It is imperative to maintain the performance and value of the state transportation assets to enable Minnesota to continue to provide safe and high-level service to its citizens.

Successful management of the state highway system relies on sound investment strategies that consider constituent input, legislative requirements, engineering needs, and fiscal constraints. Since the 1990s, MnDOT has used performance management tools to evaluate its services and to guide its plans, projects, and investment strategies.

Purpose

On July 6, 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law. It is the first long-term highway authorization enacted since 2005 to fund surface transportation programs. MAP-21 creates a streamlined, performance-based, and multimodal program to address the many challenges facing the nation's transportation system. These challenges include improving safety, maintaining infrastructure condition, reducing traffic congestion, improving efficiency of the system and freight movement, protecting the environment, and reducing delays in project delivery[2].

Under MAP-21, performance management transforms federal highway programs and provides a means to more efficient investment of federal transportation funds. It focuses on national transportation goals, increasing the accountability and transparency of the federal highway programs, and improving transportation investment decision making through performance-based planning and programming.

MAP-21 requires states to develop a risk-based asset management plan (i.e. TAMP) for the National Highway System (NHS) to improve or preserve the condition of the assets and the performance of the system. **Figure 1-1** summarizes the characteristics and benefits of a transportation asset management program[3]. The legislation focuses on the development

1 MnDOT's Office of Materials and Roads Research collects pavement condition data annually on 14,000 state highway system roadway miles. "Roadway miles" is equal to the total of undivided centerline miles of road in addition to two times the number of divided centerline roads.

2 *http://www.fhwa.dot.gov/map21*

3 Adapted from FHWA 2006, available online at: *http://www.fhwa.dot.gov/infrastructure/asstmgmt/tpamb.cfm*

of a TAMP for bridges and pavements on the NHS, but encourages states to include other infrastructure assets within the right-of-way corridor.

MnDOT elected to expand the TAMP beyond the MAP-21 requirements and include pavements and bridges on the entire state highway system as well as highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures (see **Figure 1-2**). Because MnDOT had already begun the implementation of asset management principles prior to MAP-21 legislation, it was in a better position to expand beyond the requirements of MAP-21.

Chapter 4: Asset Inventory and Condition includes folios that describe each asset category in greater detail.

The TAMP will serve as an accountability and communication tool and will inform established capital and operations planning efforts from this point forward. In addition to being a Federal requirement, the TAMP is a planning tool by which MnDOT can more thoroughly evaluate risks and develop mitigation strategies, analyze life-cycle costs, establish asset condition performance measures and targets, and develop investment strategies. It formalizes and documents the following key information, to meet MAP-21 federal requirements, into a single document:

- Description and condition of pavements and bridges on the NHS
- Asset management objectives and measures
- Summary of gaps between targeted and actual performance
- Life-cycle cost and risk management analysis
- Financial plan that addresses performance gaps
- Investment strategies and anticipated performance

Figure 1-1: Characteristics and Benefits of a Transportation Asset Management Program

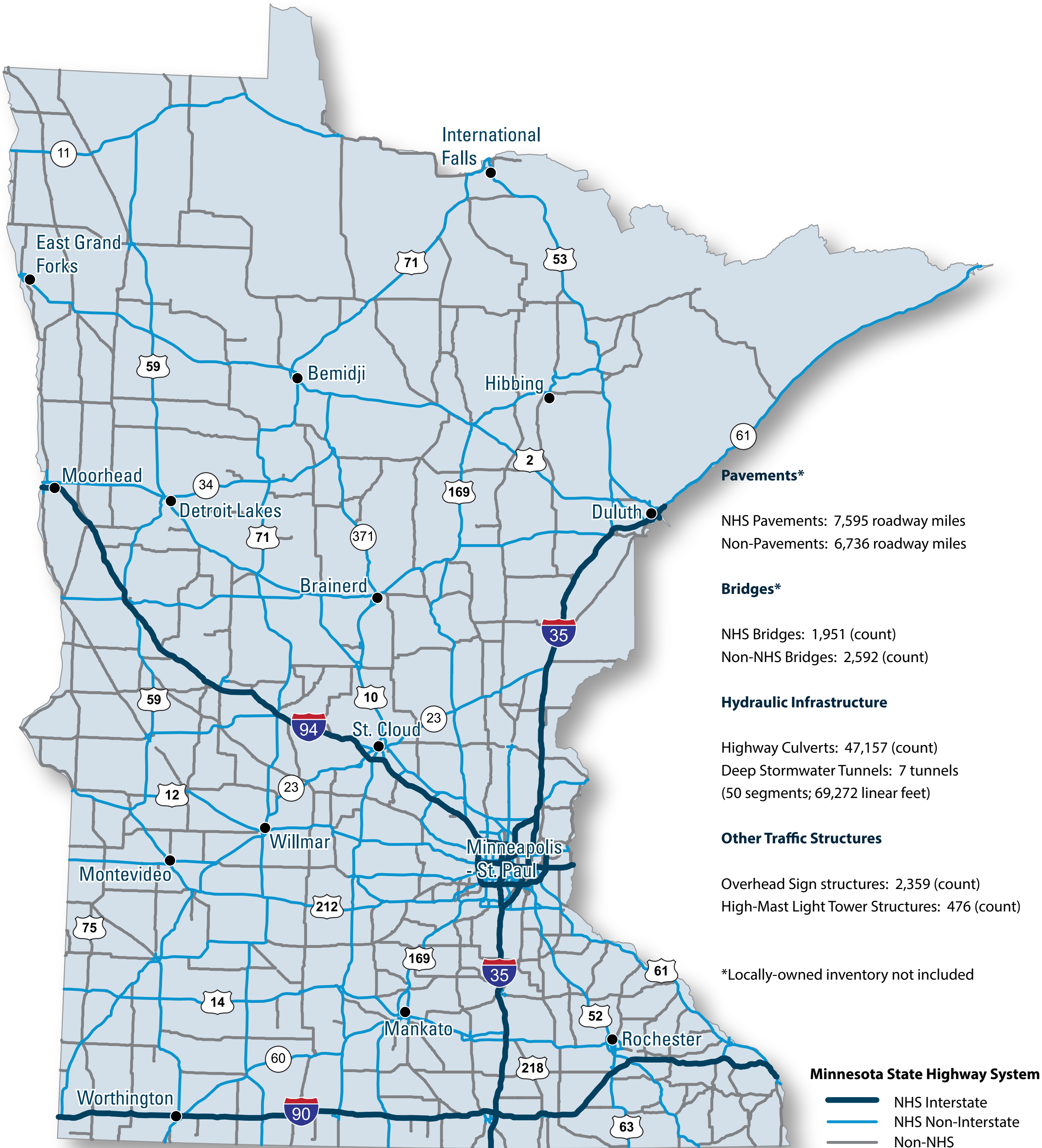
Characteristics of an Asset Management Program

- Track system condition, needs, and performance.
- Consider public expectations and desires when setting strategic objectives.
- Align agency investment decisions to achieve strategic goals.
- Use an objective process to maintain and manage assets; should consider needs, available funding, risks, operational constraints, and maintenance costs over the life of the assets.
- Determine the optimal time to improve assets based on performance data.

Benefits of Applying Transportation Asset Management Principles

- Optimize and improve transportation system performance.
- Improve customer satisfaction.
- Minimize life-cycle costs.
- Match level of service provided to public expectations.
- Make more informed, cost-effective program decisions and better utilize existing assets.
- Develop an unbiased methodology to balance trade-offs between competing objectives.

Figure 1-2: Minnesota's State Highway System



Pavements*

NHS Pavements: 7,595 roadway miles
Non-Pavements: 6,736 roadway miles

Bridges*

NHS Bridges: 1,951 (count)
Non-NHS Bridges: 2,592 (count)

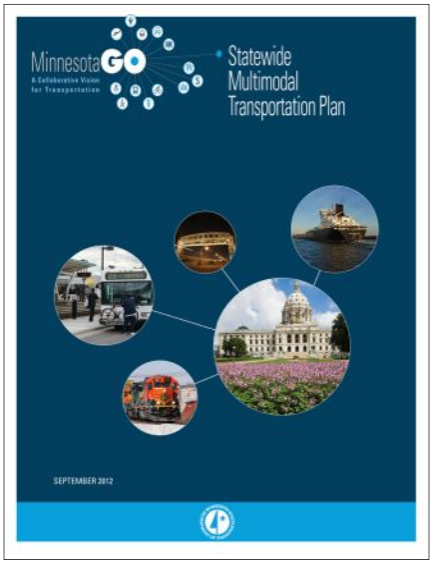
Hydraulic Infrastructure

Highway Culverts: 47,157 (count)
Deep Stormwater Tunnels: 7 tunnels
(50 segments; 69,272 linear feet)

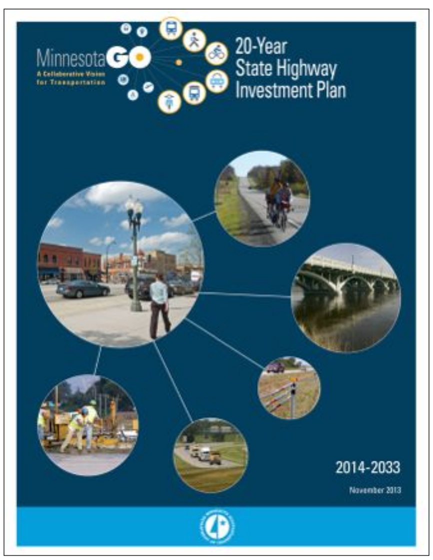
Other Traffic Structures

Overhead Sign structures: 2,359 (count)
High-Mast Light Tower Structures: 476 (count)

*Locally-owned inventory not included



The Statewide Multimodal Transportation Plan objectives shape subsequent MnDOT plans and investments.



MnSHIP directs $5.1 billion to be spent on Asset Management over the next ten years.

Asset Management Planning at MnDOT

MnDOT's asset management policy is established and continually updated through statewide performance based planning initiatives. The Minnesota GO Vision, Statewide Multimodal Transportation Plan, State Highway Investment Plan (MnSHIP), and Highway System Operations Plan (HSOP) set policy objectives and performance based targets. The Annual Minnesota Transportation Performance Report documents system performance and informs future policy and investment planning.

MINNESOTA GO VISION AND STATEWIDE MULTIMODAL TRANSPORTATION PLAN

The Minnesota GO Vision and Statewide Multimodal Transportation Plan provide the policy framework used to shape subsequent MnDOT plans and investment decisions. Both documents stress the importance of asset management –strategically maintaining and operating transportation assets.

STATE HIGHWAY INVESTMENT PLAN

The State Highway Investment Plan (MnSHIP) is MnDOT's vehicle for determining and communicating capital investment priorities for the state highway system over a 20 year planning horizon. MnSHIP establishes asset condition targets for state highway pavement and bridge assets and sets funding levels for asset management at $5.1 billion (representing 68 percent of planned capital expenditures) over the first 10 years (2014-2023).

HIGHWAY SYSTEMS OPERATION PLAN

The Highway Systems Operation Plan (HSOP) provides a framework for managing key operations and maintenance activities throughout Minnesota. A key focus of HSOP is infrastructure asset management and being able to make decisions using total life-cycle costs by considering trade-offs in maintenance activities.

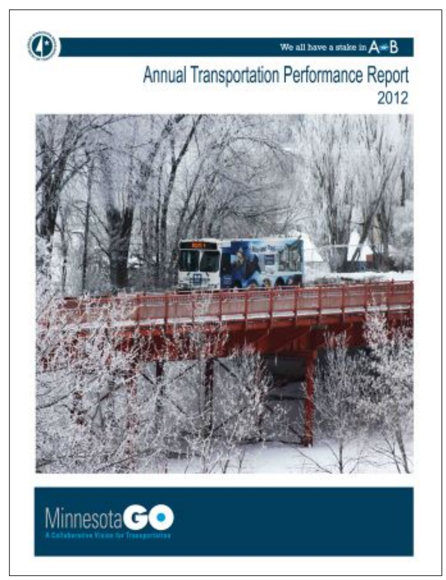
ANNUAL TRANSPORTATION PERFORMANCE REPORT

The (2012) Annual Transportation Performance Report describes trends in the condition and service levels for Minnesota's transportation systems. It summarizes the plans, investments, strategies and innovations MnDOT and its partners use to optimize performance, and tracks progress in 10 performance areas, asset management being one.

The report indicates:

"MnDOT expects pavement preservation needs to grow faster than available resources. Anticipating this scenario, MnSHIP directs MnDOT to focus pavement investment on the NHS with the objective of maintaining existing ride quality through 2023. Doing this also means the percentage of non-NHS highways with Poor ride quality will grow from 7.5 percent in 2012 to 12 percent in 2023. Minnesota's bridges will remain safe. Under current projections, by 2033 the share of NHS deck area in Poor condition will rise to between six and eight percent."

HSOP documents the management of non-capital highway investments for the next four years.



The Annual Performance Report indicates the percentage of non-NHS highways with Poor ride quality will grow from 7.5 percent in 2012 to 12 percent in 2023.

Process

This Transportation Asset Management Plan is the product of a 12 month process that involved a Steering Committee, Project Management Team, and four technical Work Groups.

The **Steering Committee** provided direction and oversight during TAMP development, and included broad representation across the agency and from Minnesota's Federal Highway Administration (FHWA) Division office. Steering Committee representation included:

- FHWA Division Office

- Minnesota Department of Transportation
- Bridge
- Data & Analysis
- Districts
- Executive Management
- Finance
- Investment Planning
- Maintenance & Operations
- Materials (Pavement)
- Performance Measures
- Policy Planning
- Risk
- Traffic, Safety, and Technology
- Transportation Systems Management

The **Project Management Team (PMT)**, a sub-set of the Steering Committee, was responsible for day-to-day work activities.

Work Groups were developed for each broad asset category: pavement, bridge, hydraulics, and other traffic structures. Each was comprised of subject matter technical experts and had a group lead or main contact. Highway culverts and deep stormwater tunnels were discussed together with the Hydraulic Work Group, while overhead sign structures and high-mast light tower structures were discussed together by the Other Traffic Structures Work Group. Work Groups were invaluable with efforts to document current practices, determine data availability, assess risks and propose mitigation strategies, and identify targets and investment strategies.

TAMP Themes

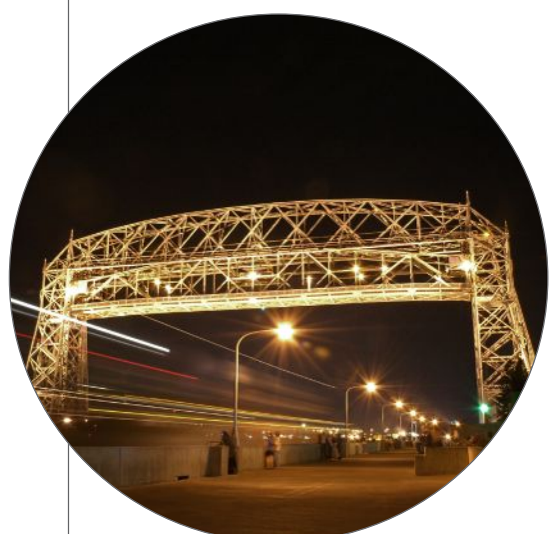
Four themes emerged during development of the TAMP that influenced recommendations, refined investment strategies, and identified enhancements.

- **Improve the consideration of maintenance costs in capital investment decisions.** In most transportation agencies, long-term maintenance costs associated with capital improvements are not fully considered when making investment decisions. While developing the TAMP, steps were taken to improve the consideration of maintenance costs when evaluating capital investments.

- **Reduce business and asset-specific risks.** A number of business process changes were identified to reduce agency risk. Several of these changes have already been implemented are currently being implemented. For example, MnDOT is in the process of developing a Transportation Asset Management System (TAMS) that will allow MnDOT to better manage roadside infrastructure data: location; work activity history; equipment; materials; and staffing needs. Asset-specific undermanaged risks and mitigation strategies were also identified and incorporated in the TAMP.

- **Build on existing plans, information, and processes.** MnDOT has a history with and commitment to risk based and performance based planning. (e.g., MnSHIP, HSOP, etc.). The intent of the TAMP is to build upon and enhance but not supplant established planning processes.

- **Identify and address gaps in data and business processes.** MnDOT elected to expand the use of asset management principles to a broader collection of assets beyond pavements and bridges, even though limited information was available for these assets. As a result, MnDOT has a better understanding of the information needed to more effectively manage these assets and has taken steps to obtain this information in support of both ongoing asset management and future capital and operational planning efforts.



TAMP Content

The TAMP is presented in nine chapters.

- **Chapter 1: Introduction** – This chapter provides an overview of current asset management policy and investment plans, purpose for developing a TAMP, general process during development, and information contained in each chapter.

- **Chapter 2: Asset Management Planning and Programming Framework** – This chapter summarizes the connection of existing asset management direction, policy, and programming at MnDOT to the TAMP.

- **Chapter 3: Asset Management Performance Measures and Targets** – This chapter summarizes MnDOT's existing (pre-TAMP) performance measures and MnSHIP targets for pavement and bridge, and the new (TAMP) target terminology that will replaced existing MnSHIP target definitions.
- **Chapter 4: Asset Inventory and Condition** – This chapter summarizes information about all six asset categories analyzed in this TAMP, and includes data on inventory, condition, and replacement value.
- **Chapter 5: Risk Management Analysis** – This chapter provides an overview of risk and why it's important, a summary of MnDOT's current risk structure, and risks associated with undermanaging transportation assets and strategies to mitigate these risks.
- **Chapter 6: Life-Cycle Cost Considerations** – This chapter describes life-cycle cost analysis and highlights strategies for managing assets. It includes a cost-effectiveness comparison of MnDOT's current (or typical) approach vs. other approaches (i.e. desired or worst-first) to managing each asset.
- **Chapter 7: Performance Gaps** – This chapter highlights existing performance measures and targets identified in MnSHIP, MnDOT's new direction for targets and agency commitments, and new TAMP target recommendations for consideration during development of the next MnSHIP.
- **Chapter 8: Financial Plan and Investment Strategies** – This chapter presents a financial outlook based on recent trends and assumptions, summarizes capital and maintenance investments for the next 10 years, and describes how different capital investment scenarios considered risk. It also outlines the committed revenue and revenue needs to meet expected performance outcomes over the next 10 years.
- **Chapter 9: Implementation and Future Developments** – This chapter summarizes the important actions or desired takeaways identified during the development of this TAMP. Governance of the TAMP is also important, and this chapter identifies implementation steps to continually make progress toward better asset management. It also presents recommendations for future updates to the TAMP.

In addition to the TAMP, a **Technical Guide** was prepared and published separately. The **Technical Guide** includes additional information on each chapter of the TAMP. It frames information around "process" and "supporting data and documentation," and includes additional technical information to supplement the TAMP.

Chapter 2

ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK

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ASSET MANAGEMENT OBJECTIVES

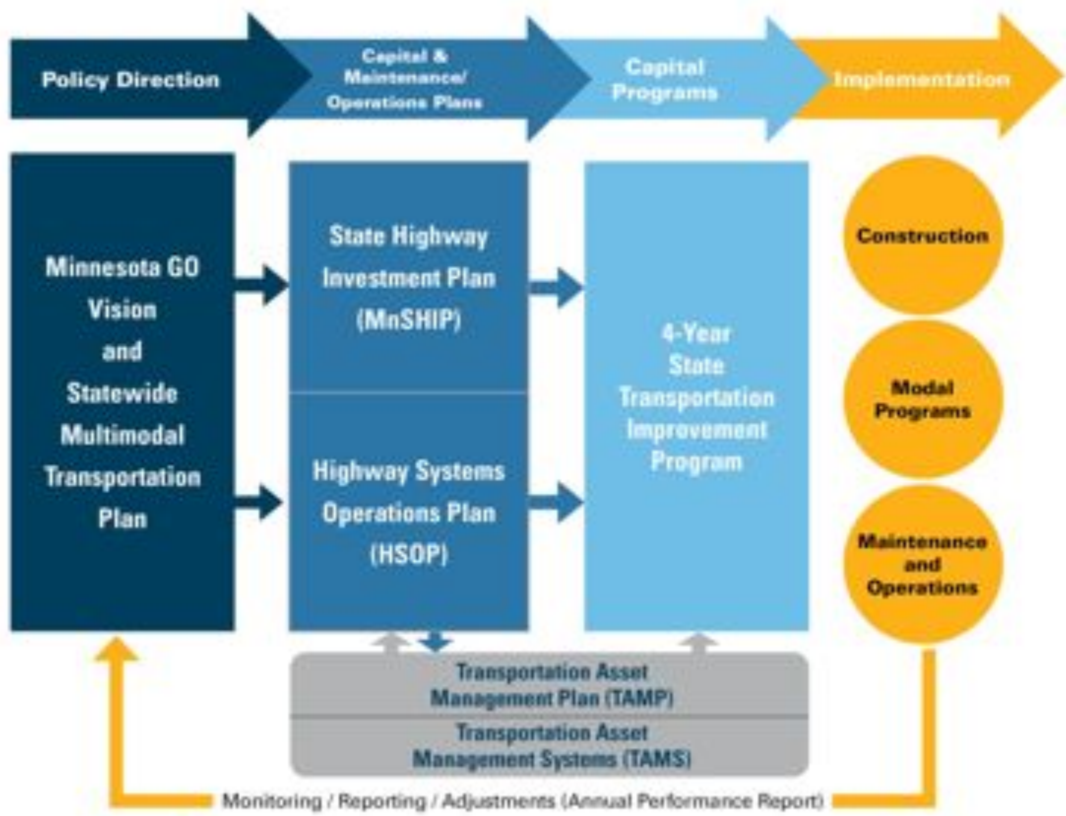
Overview

MnDOT has strong business processes currently in place to prioritize asset management investments in Minnesota's transportation infrastructure. Asset management is understood at MnDOT as the effective use of available resources to make the right investment decisions and minimize asset life-cycle costs, while considering the various tradeoffs involved in decision-making processes. This is in line with the definition of asset management outlined in MAP-21:

Asset management is a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life-cycle of the assets at minimum practicable cost.

A simplified schematic of the investment process, showing the link between the existing agency plans and the TAMP, is represented in **Figure 2-1**.

Figure 2-1: MnDOT Asset Management Planning Process



MnDOT's priorities and objectives are reflected in its investment plans, which include the 20-year State Highway Investment Plan (MnSHIP) for capital improvements and the 4-year Highway System Operations Plan (HSOP) for maintenance and operations investments. MnSHIP and HSOP are a part of the coordinated, ongoing planning and outreach process that connects policy direction – laid out in Minnesota's 50-year Statewide Vision (the "Minnesota GO Vision") and 20-year Statewide Multimodal Transportation Plan (SMTP) – to improvements made on the state highway system.

These plans document the investment strategies and expected outcomes for pavements and bridges that have been incorporated into this TAMP, as well as for other investments beyond the TAMP's scope. Future MnDOT TAMPs (see gray box in **Figure 2-1**) will serve as supporting documents that influence updates of MnSHIP and HSOP, objectives related to asset preservation, and system safety and reliability measures. The TAMP does not replace any existing MnDOT plan; rather, it provides critical input to existing plans, linking capital and maintenance expenditures related to asset preservation.

Existing Asset Management Policy

MINNESOTA GO VISION

MnDOT's long-term (50-year) vision is to provide a sustainable multimodal transportation system that improves the quality of life, environmental health, and overall economic competitiveness of Minnesota. As outlined in the Minnesota GO Vision, the role of the transportation system is to:

- Connect Minnesota's primary assets – the people, natural resources and businesses within the state – to each other and to markets and resources outside the state and the country.
- Provide a safe, convenient, efficient, and effective movement of people and goods.
- Provide a flexible system to adapt to changes in society, technology, environment, and the economy.

The Minnesota GO Vision guiding principles, which direct MnDOT's policy and investment decisions related to transportation assets, are summarized in **Figure 2-2**.

Figure 2-2: Guiding Principles for MnDOT's Policy and Investment Decisions

LEVERAGE PUBLIC INVESTMENTS TO ACHIEVE MULTIPLE PURPOSES	• Provide a transportation system to support other public purposes such as environmental stewardship, economic competitiveness, public health, and energy.
ENSURE ACCESSIBILITY	• Provide a safe system for user of all abilities and incomes. • Provide access to key resources and amenities.
BUILD TO A MAINTAINABLE SCALE	• Consider and minimize long-term obligations. • Affordably contribute to overall quality of life and prosperity of the state.
ENSURE REGIONAL CONNECTIONS	• Connect key regional centers through multiple modes of transportation.
INTEGRATE SAFETY	• Improve safety through systematic and holistic methods that take into account proactive, innovative and strategic considerations.
EMPHASIZE RELIABLE AND PREDICTABLE OPTIONS	• Prioritize multimodal options over reliance on a single option.
STRATEGICALLY FIX THE SYSTEM	• Strategically maintain and upgrade critical existing infrastructure.
USE PARTNERSHIPS	• Coordinate across sectors and jurisdictions to improve efficiency of transportation projects and services.

STATEWIDE MULTIMODAL TRANSPORTATION PLAN

MnDOT's Statewide Multimodal Transportation Plan (SMTP), adopted in 2012, identifies objectives and strategies to help achieve the Minnesota GO Vision. The plan emphasizes multimodal solutions that ensure high return-on-investment. The SMTP objectives, summarized in **Figure 2-3**, include Asset Management as one of six key focus areas, stressing the importance of data in strategically operating and maintaining the transportation system.

Figure 2-3: MnDOT's Statewide Multimodal Transportation Plan Objectives

ACCOUNTABILITY, TRANSPARENCY, AND COMMUNICATION
• Have a data-driven decision process. • Support coordination, collaboration, and innovation. • Ensure efficient and effective use of resources.
TRAVELLER SAFETY
• Safeguard travelers, transportation facilities, and services. • Use proven strategies to reduce fatalities and serious injuries in all modes of travel.
TRANSPORTATION IN CONTEXT
• Make fiscally responsible decisions that respect the context of place. • Integrate land use and transportation systems.

CRITICAL CONNECTIONS
• Identify, maintain, and improve essential transportation connections while considering new connections.
ASSET MANAGEMENT
• Maintain and operate transportation assets strategically.
• Use system data and consider needs of MnDOT's partners and public expectations to inform decisions.
SYSTEM SECURITY
• Reduce vulnerability and ensure redundancy to meet travel needs during emergencies.

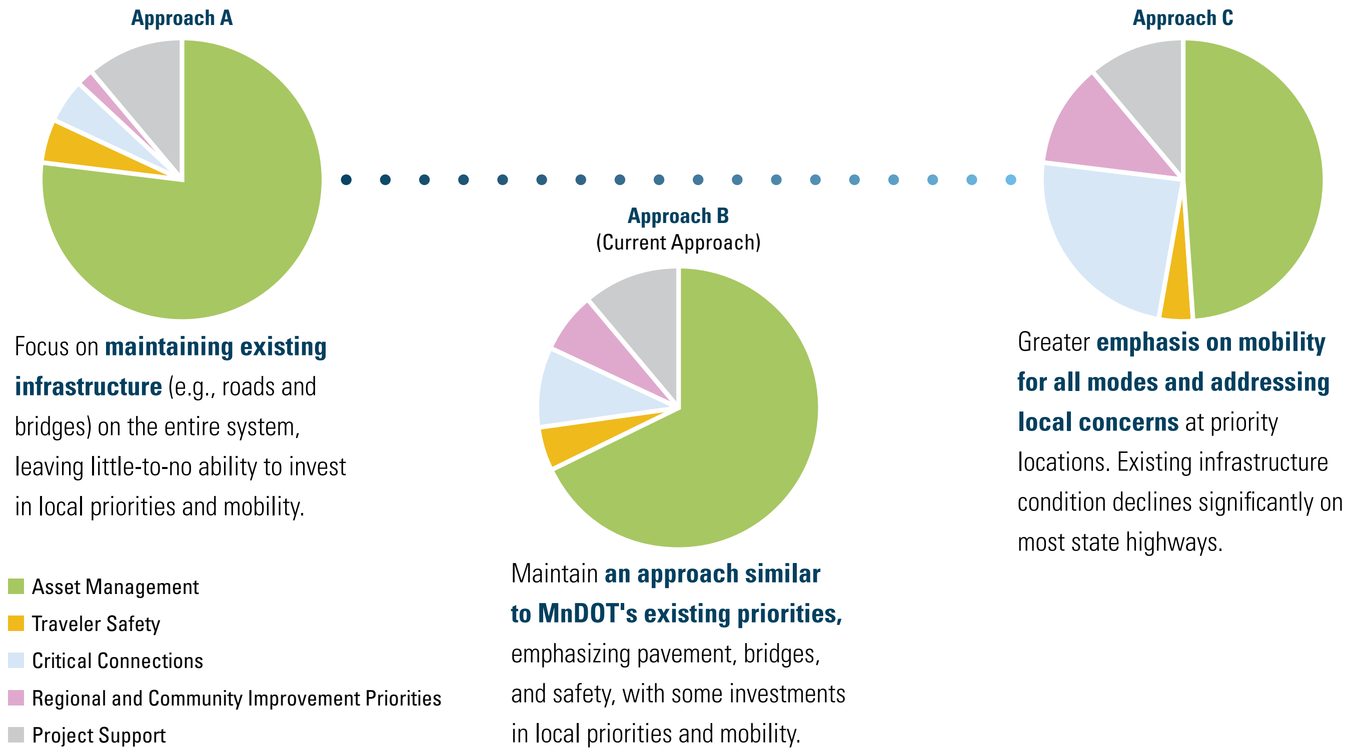
STATE HIGHWAY INVESTMENT PLAN

MnDOT documents its capital investment strategies to address all six of the above SMTP objectives in the State Highway Investment Plan (MnSHIP), which is a 20-year fiscally constrained plan. MnSHIP analyzes and tracks the impact of recent capital investments, identifies capital needs, establishes statewide priorities for projected revenue, and identifies strategies that ensure that MnDOT resources are used efficiently and effectively. The 2013 plan predicts revenues for the next 20 years to total $18 billion, although the projected needs on the transportation system total $30 billion. This $12 billion funding gap is projected to result in an increase in both the number of roads and bridges in Poor condition and the number of unfunded priorities over the 20-year planning horizon.

The growing disparity between available resources and the investments needed to maintain the transportation infrastructure system at a desired level of service has been the guiding focus for the major themes identified during the development of the TAMP (discussed in **Chapter 1**). These themes include emphasis on maintenance and preservation of existing transportation assets and enhancing current business processes to improve management of transportation assets.

The use of a risk-based approach to inform investment and project decisions is not a new concept for MnDOT. During the MnSHIP development process, tradeoffs between investment levels, performance levels, and risks were evaluated to improve understanding of the impact of investment decisions through a more holistic approach. **Figure 2-4** summarizes three approaches developed during the MnSHIP scenario planning process.

Figure 2-4: Investment Approaches Developed for Scenario Planning



The primary intent of comparing the three approaches discussed above was to demonstrate a range of possible objectives that MnDOT could pursue over the next two decades, as well as to evaluate the tradeoffs in performance and risk management within each approach. External and internal outreach efforts were conducted to gather input on the investment approaches. Two primary risks were identified through the outreach process:

- Failure to implement federal policy set in MAP-21
- Failure to preserve the state's bond rating by falling below the thresholds set in Government Accounting Standards Board Statement 34 (GASB 34)

These risks were used as the guiding focus in the development of the final MnSHIP investment strategies discussed in **Chapter 8: Financial Plan and Investment Strategies**. For the first 10 years, the adopted investment strategy emphasizes maintaining a diverse mix of improvements to reduce overall life-cycle costs, as well as enhancing mobility and MnDOT's ability to respond to evolving needs.

MNSHIP CAPITAL INVESTMENT PRIORITIES

For the 10-year period addressed in this TAMP, MnDOT will balance its investments in infrastructure preservation with new multimodal transportation connections and other projects that advance economic development and quality of life in Minnesota. These latter projects, which are funded via non-preservation investment categories (e.g. regional and community improvement priorities, accessible pedestrian infrastructure, bicycle infrastructure, traveler safety), reflect stakeholder input. They adequately manage key capital investment risks and honor current programming commitments.

The infrastructure preservation investments documented in this TAMP are targeted to optimize investments in asset management (considering fiscal constraints) while making progress toward established goals and objectives. **Figure 2-5** summarizes the specific strategies that MnDOT adopted as a part of the MnSHIP development process to better manage performance in various capital program areas over the next 10 years. The TAMP focuses specifically on the strategies within the Asset Management category.

Figure 2.5: Capital Strategies for More Efficient Asset Investments

INVESTMENT CATEGORY	10-YEAR STRATEGY
Asset Management - Pavements	• Maintain conditions on NHS pavements. • Allow non-NHS pavements to deteriorate to a slightly lower condition, while maintaining safe conditions for the traveling public. • Use low-cost maintenance and preservation strategies. • Use performance-based design to select projects that address pavement and safety needs. • Alternate bidding and contracting mechanisms to determine the most cost-effective solutions. • Research/evaluate innovative materials and construction techniques.
Asset Management - Bridges	• Maintain condition of NHS bridges. • Allow non-NHS bridges to deteriorate to a slightly lower condition, while keeping them safe and operable to the traveling public. • Invest in state highway bridges at optimum points in their life- cycles to ensure safety and structural health. • Conduct bridge inspections to ensure timely application of maintenance and capital improvements. • Apply appropriate measures to ensure bridges achieve or exceed their intended service lives.

INVESTMENT CATEGORY	10-YEAR STRATEGY
Asset Management - Roadside Infrastructure	• Maintain culverts, signals, sign structures, sign panels, lighting structures, rest areas, barriers, and retaining walls in safe operable conditions with the understanding that their general conditions are expected to deteriorate with current expected funding levels.
Traveler Safety	• Lower annual fatalities and continue to partner in the Toward Zero Deaths (TZD) initiative. • Invest in low-cost high-benefit treatments (for example, using guardrails along sharp curves). • Track and address locations with a history of crashes.
Critical Connections - Twin Cities Mobility	• Focus on active traffic management, strategic capacity improvements, and high-occupancy vehicle (MnPASS) lanes.
Critical Connections - Interregional Corridor Mobility	• Maintain the interregional corridor system mobility performance target.
Critical Connections - Bicycle Infrastructure	• Use bridge and pavement projects to accommodate bicyclists as appropriate. • Focus on stand-alone projects at high priority locations.
Critical Connections - Accessible Pedestrian Infrastructure	• Accommodate pedestrian accessibility concurrent with pavement and bridge projects. • Ensure that a majority of curb ramps and signalized intersections are maintained to ADA standards.
Regional and Community Improvement Priorities	• Address economic vitality and quality of life through partnerships, design add-ons, and a few stand-alone projects each year.
Project Support	• Make investments to support the delivery of projects in other categories.
Small Programs	• Ensure system resiliency to respond to unforeseen issues, one-time needs, or changes in policy/funding.

HIGHWAY SYSTEM OPERATIONS PLAN

HSOP provides a framework for managing key operations and maintenance activities throughout Minnesota and complements other strategic planning efforts, such as MnDOT's District Highway Investment Plans, which focus on capital infrastructure needs. In addition, HSOP builds on prior efforts for performance-based planning and data-driven decision making. The primary objective of the plan is to document the management of non-capital highway investments over the next four years.

HSOP themes that serve as a framework for operations and maintenance activities include:

- **Safety** – Systematically and holistically improve safety.
- **Good Stewards of the Environment** – The transportation system should support other public purposes, such as environmental stewardship, sustainable solutions, economic competitiveness, public health, and energy independence.

- **Seek Innovation** – Be proactive, innovative, strategic, and more efficient in operations and maintenance activities.
- **Infrastructure Asset Management** – Strategically maintain and upgrade critical existing infrastructure. Create a knowledge base to make decisions using life-cycle costs in the future. Identify inventory degradation and tradeoffs for maintenance activities.
- **Understanding System and Cost Trends** – Consider and minimize long-term obligations; do not overbuild. Use a life-cycle approach to focus on building only what MnDOT can sustain with regard to operations and maintenance. The scale of the system should reflect and respect the surrounding physical and social context.

The plan provides background information on factors influencing overall operations and maintenance activities, summarizes each work activity area, and identifies key implementation strategies to improve performance. It also identifies risk and investment strategies as part of a budget summary and gap analysis and provides findings and recommendations.

As part of this HSOP, a more formal Enterprise Risk Management (ERM) approach was used to help determine funding gaps and areas where additional funding could be directed if it became available. ERM involves identifying particular events or circumstances relevant to MnDOT's objectives (risks and opportunities), assessing them in terms of likelihood and magnitude of impact, determining a response strategy, and assessing the effectiveness of the response strategy in reducing overall risks.

HSOP OPERATIONS AND MAINTENANCE INVESTMENT PRIORITIES

HSOP identifies current operations and maintenance revenues for the next four years (2012-2015) of approximately $860 million, with a need of approximately $1.25 billion over this same timeframe. This results in a gap of approximately $390 million (or almost $410 million if inflation is included). As part of the ERM process, a flat budget was assumed for the next four years. Given this assumption and the impacts of inflation, business-as-usual will not manage operational risks to the extent needed. **Figure 2-6** summarizes specific findings and recommendations (i.e. strategies) adopted by MnDOT (as part of the HSOP development process) to better manage operations and maintenance performance.

Figure 2-6: Maintenance/Operations Findings and Recommendations for More Efficient Asset Management

FINDING	RECOMMENDATION (STRATEGY)
Aging Assets: As the state's infrastructure continues to age, much of it is either nearing or is beyond its useful life, thus creating significant operations and maintenance challenges.	Continue to place emphasis on preserving assets that are critical to the safety, mobility, and functionality of the transportation system.
Increasing Costs: Maintaining the current system is a very labor- and equipment-intensive task.	Research and develop new techniques, strategies, and processes to minimize costs and remain current with industry standards.
Growing Number of Assets: Increases in transportation system assets (e.g. complex interchange designs, traffic control devices) result in greater needs for operations and maintenance funds.	Continue to explore opportunities to provide low-cost, high-benefit improvements, but recognize that many of these elements place additional burdens on operations and maintenance forces, and consider the total project cost, not just the initial capital cost for construction.
Impacts of Capital Budget / Total Project Cost: Greater investment in the capital budget typically results in a reduced need for operations and maintenance, whereas reduced capital investment typically results in greater need for operations and maintenance.	Approach cost estimation on a "total project cost" basis in order to address cost management from conception to completion. This would consider the operating and maintenance costs associated with the project.
Mandates: Increased responsibilities and additional costs often accompany mandates, which require MnDOT to provide additional or new services that typically have not been accounted for in the past.	Actively communicate the costs and impacts associated with new mandates in order to try to avoid resource redirection or shortfalls in other areas.
Decreasing Staff Levels: A number of work activity areas are not able to address all of their required tasks with their current staff levels. Alternately, there are inefficiencies created due to a lack of staffing.	Continually evaluate staffing needs and identify opportunities to train staff in various work activities for organizational efficiency.
Use of Technology / Innovation: MnDOT work activities regularly use technology and innovative strategies to increase efficiencies and are involved with a number of research partnerships and activities.	Continue to seek and support technological enhancements that help the agency better track inventories and asset condition (e.g., traffic signals, fleet, sign management).
Preventive Maintenance: A preventive maintenance program can reduce overall operations and maintenance costs by regularly providing service and avoiding larger maintenance or capital costs.	Focus on preventive maintenance activities that will prolong service life and help avoid significant capital investments until the product has fulfilled its useful service life. Continue to evaluate preventive maintenance activities with less clear benefits.

Collectively, the Minnesota GO Vision, SMTP, MnSHIP, and HSOP documents establish MnDOT's direction and identify the strategic priorities that are considered in planning Minnesota's transportation future.

Existing Asset Management Programming Framework

Once investment levels are established, projects are selected to help achieve the targeted performance expectations established by MnDOT. The agency has several tools available to help determine the best use of available funding for asset management activities. For instance, MnDOT manages pavement condition data through its Highway Pavement Management Application (HPMA) software. MnDOT uses HPMA to develop funding scenarios based on pavement treatment decision trees and performance prediction models to optimize the combination of preservation and rehabilitation activities and achieve the best conditions possible.

For bridges, MnDOT has chosen to integrate commercial bridge management software (Pontis) with the agency's home-grown Bridge Replacement and Improvement Management (BRIM) system. Pontis is currently being upgraded to include models that will allow MnDOT to predict future bridge conditions. The BRIM system allows MnDOT to prioritize bridge investments based on risk and importance factors. It generates a bridge planning index score for each bridge in the state. Each bridge's score is based on risk factors (e.g. fracture criticality, substandard vertical clearance) and importance factors (e.g. bridge length, traffic volume).

Finally, MnDOT has a maintenance management program for tracking maintenance and operations activities. This system is also scheduled for enhancements in the next several years.

Programmed projects are based on recommendations from the management systems and input from MnDOT district personnel. The projects are part of the Statewide Transportation Improvement Program (STIP), which details federal and state funding allocations to state and local projects. Annual work plans for needed maintenance and operations activities are then derived from the STIP.

MnDOT is also in the process of implementing management systems for asset categories beyond pavements and bridges. These systems, collectively referred to as Transportation Asset Management Systems (TAMS), will allow MnDOT to better manage roadside infrastructure through a more objective, data-driven approach. The first TAMS implementation will focus on traffic signals and lighting.

Chapter 3

ASSET MANAGEMENT PERFORMANCE MEASURES AND TARGETS

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ASSET MANAGEMENT PERFORMANCE MEASURES AND TARGETS

Overview

MnDOT has used a performance-based approach to managing its transportation assets since the mid-1990s and made it a formal part of its business process in 2003. The ongoing measurement and review process allows MnDOT to evaluate the efficiency of service delivery and to assess the effectiveness of program activities. This objective-based approach increases transparency and encourages innovation by keeping the focus on outcomes.

Existing Performance Measures and Targets

MnDOT's performance-based approach to asset management relies on **performance measures** to assess system performance, identify needs, and develop investment priorities. Historically, these measures have included state highway ride quality and bridge condition. Additional performance measures, tracking things like culvert and stormwater tunnel condition, have been monitored and used internally for managing asset-specific programs; however, they have not been used at the system level for establishing budget requirements. **Figure 3-1** lists MnDOT's performance measures as of the 2013 adoption of the State Highway Investment Plan (MnSHIP), by asset category. Short descriptions of each measure's rating scale and criteria are also included, along with MnSHIP targets, where applicable. Targets are the subject of the final two sections of this chapter. Visual representations of the performance rating scales can be found in **Figure 4-5**, **Figure 4-6**, **Figure 4-7**, and **Figure 4-8** in the next chapter.

As part of its pavement and bridge management activities, MnDOT regularly conducts condition surveys in order to identify deficiencies in need of addressing. For pavements, MnDOT uses a specialized van that collects data regarding the amount of cracking present and the smoothness of the ride. This information is used to determine a Surface Condition Rating and a Ride Quality Index, the latter of which defines whether a road is in Good, Fair, or Poor condition. A Pavement Quality Index, which combines surface condition and ride quality ratings, is also calculated for reporting statewide conditions and to determine if other agency performance requirements are met (see discussion of GASB 34, below). Information regarding pavement condition on the National Highway System (NHS) is reported to the Federal Highway Administration (FHWA) each year.

Most bridges are inspected on two-year intervals; results are reported to the FHWA. Bridge inspections assess the condition of the decks, superstructures, substructures, and culverts using a standardized, national survey procedure. Inspection results are used to determine which bridges are in Good, Satisfactory, Fair, or Poor structural condition. Bridges in Good, Satisfactory or Fair condition generally require only maintenance or preservation activities, while bridges in Poor condition may require major capital investments.

Inspections of other assets are typically performed less frequently. For highway culverts, a MnDOT-developed statewide geographic information application – known as HydInfra – is used to manage the inventory, as well as inspections and maintenance activities. During inspections, a condition rating is assigned to each culvert. The ratings range from 1 to 4, with 1 representing a feature in Like New condition and 4 representing a feature in Very Poor condition with serious deterioration. In addition to reporting the feature condition, the HydInfra rating is used to set the inspection frequency. For instance, pipes with an overall rating of 4 (Very Poor) may be inspected annually or every two years, while a pipe with a rating of 1 or 2 (Like New or Fair) may be inspected as infrequently as once every six years. Deep stormwater tunnel inspection and reporting protocols are currently being updated to align with those of highway culverts.

Overhead sign structures were recently inspected by an independent consultant hired by MnDOT. Efforts are underway to develop a standardized inspection procedure for overhead sign structures. An inspection process for high-mast light tower structures was developed in 2001 and recently updated.

Figure 3-1: Performance Measures by Asset Type

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	TARGET
Pavements	Share of system lane miles with Poor ride quality	Ride quality is assessed using MnDOT's Ride Quality Index, which is a measure of pavement smoothness as perceived by the typical driver. Pavement rated Poor can still be driven on, but the ride is sufficiently rough that most people would find it uncomfortable and may decrease their speed.	≤ 2% (NHS) ≤ 3% (Non-NHS)
Bridges	NHS bridges in Poor condition as a percent of total NHS bridge deck area	Bridge condition is calculated from the results of inspections on all state highway bridges. The ratings combine deck, superstructure, and substructure evaluations. Bridges rated Poor are safe to drive on but are reaching a point where it is necessary to either replace the bridge or extend its service life through significant investment.	≤ 2% (NHS) ≤ 8% (Non-NHS)
Highway Culverts	Share of culverts in Poor or Very Poor condition	Highway culvert condition is assigned during inspections. Culverts in Poor condition display cracks or joint separation, while those in Very Poor condition exhibit holes and more significant joint separation resulting in a loss of surrounding (road bed) material.	NA

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	TARGET
Deep Stormwater Tunnels	Tunnels in Poor and Very Poor condition, measured as a percent of total tunnel system length	Deep stormwater tunnel condition is assigned during inspections. Inspections identify and measure cracks, fractures, and voids behind the tunnel liners. Tunnels in Poor condition have significant cracks and voids behind the unreinforced tunnel liner. Tunnels in Very Poor condition display defects that require timely corrective action.	NA
Overhead Sign Structures	Share of overhead sign structures in Poor or Very Poor condition	Overhead sign structure condition is assigned during inspections. Poor and Very Poor condition is dependent on a number of criteria, including the number of untightened nuts per structure or the need to remove grout, re-grade footing, replace welds, or replace the foundation.	NA
High-Mast Light Tower Structures	Share of High-Mast Light Tower Structures in Poor or Very Poor condition	High-mast light tower structures are not currently assigned an overall condition rating; rather each individual element (e.g. foundation, anchor rods, base plate, towers, power/luminaires, winch/cables) is given a condition rating. As a result, MnDOT is in the process of redefining the criteria and rating protocols to be able to assign an overall structure condition rating. For the purposes of this TAMP, asset experts used engineering judgment to assign overall condition ratings based on individual element conditions (identified in **Chapter 4**).	NA

Notes: MnDOT uses multiple measures to evaluate the effectiveness of its pavement and bridge management activities. The measures listed here are those used to calculate MnDOT's performance-based investment needs. For a more comprehensive listing of MnDOT's pavement performance measures, see the *2013 Pavement Condition Annual Report*. Additional bridge measures can be found in MnDOT's *Annual Transportation Performance Report*.

The targets in the figure above represent desired outcomes. MnDOT sets targets based on assessments of traveler expectations and the agency's stewardship responsibilities. As a communication tool, targets allow MnDOT to contrast current and anticipated performance with outcomes representing the achievement of strategic goals. These targets, which MnSHIP refers to as "aspirational", also serve as the basis for MnDOT's unconstrained investment need. Of the $30 billion 20-year need reported in MnSHIP, $16 billion (53 percent) reflects the cost to meet MnDOT's ride quality and bridge condition targets.

TARGETS REPORTED IN MNSHIP

In 2012 MnDOT began to develop the concept of constrained targets to help manage system performance within the confines of available resources. The first constrained target MnDOT established directed the agency to maintain the share of all state highways with Poor ride quality between five and nine percent. While less than desirable, this range represents an achievable level of service that MnDOT believes is acceptable to the public and sufficient to mitigate risks associated with asset deterioration. The concept of constrained targets was carried forward into MnSHIP, where it was used to respond to federal and state performance requirements.

When MAP-21 was signed into law in 2012, it streamlined the federal highway program through a restructuring that directs the majority of funding to the NHS. It also required states to demonstrate progress toward seven national goal areas using a limited number of national performance measures. The US Department of Transportation is developing performance measures relating to fatalities, serious injuries, asset condition, system reliability, congestion reduction, on-road mobile source emissions, and freight movement. In terms of asset condition, MAP-21 specifies that national performance measures cover pavement condition on the Interstate System, pavement condition on the NHS (excluding Interstate highways), and NHS bridge condition.

At the state level, Minnesota has adopted the Government Accounting Standards Board Statement Number 34 (GASB 34) financial reporting requirements for establishing the value of its major infrastructure assets. As part of this process, MnDOT set minimum performance thresholds for the condition of state highway pavement and bridges. MnDOT must maintain pavement and bridge assets at or above GASB 34 thresholds to avoid a potential downgrade of the state's bond rating. The thresholds are presented below.

- Pavements
- Average PQI of 3.0 or higher on NHS routes (MnDOT estimates that an NHS with an average PQI of 3.0 or higher is likely to have Poor ride quality on no more than 10 percent of its roadways miles.)
- Average PQI of 2.8 or higher on non-NHS routes (MnDOT estimates that a non-NHS with an average PQI of 2.8 or higher is likely to have Poor ride quality on no more than 13 percent of its roadways miles.)

- Bridges
- At least 92 percent of NHS bridges in Fair to Good condition (i.e. no more than 8 percent in Poor condition)
- At least 80 percent of the Non-NHS bridges in Fair to Good condition (i.e. no more than 20 percent in Poor condition)

MnSHIP responded to MAP-21 and GASB 34 requirements by establishing two sets of constrained targets for ride quality and bridge condition—one set of targets for the first 10 years of the planning horizon and one set of less official targets for the second 10 years. Constrained targets in the first 10 years are referred to in MnSHIP as either "MAP-21 targets" or "10-year anticipated outcomes" (see **Figure 3-2**). These targets/outcomes represent levels of service that MnDOT is committed to providing over the first 10 years of MnSHIP's planning horizon in order to meet MAP-21 requirements.

Figure 3-2: MnSHIP Targets, Performance Thresholds, and Anticipated Outcomes

ASSET TYPE	PERFORMANCE MEASURE	TARGET	GASB 34 THRESHOLDS	CONSTRAINED TARGETS 10-YEAR ANTICIPATED OUTCOMES
Pavements	Share of system with Poor ride quality in travel lane	≤ 2% (NHS) ≤ 3% (Non-NHS)	≤ 10% (NHS) ≤ 13% (Non-NHS)	2% (NHS Interstate) 4% (Other NHS) 12% (Non-NHS)
Bridges	NHS bridges in Poor condition as a percent of total NHS bridge deck area	≤ 2% (NHS) ≤ 8% (Non-NHS)	≤ 8% (NHS) ≤ 20% (Non-NHS)	2% (NHS) 6% (Non-NHS)

TARGET TERMINOLOGY IN THE TAMP

Constrained targets are a useful tool for communicating and managing system performance in the face of severe resource limitations. Constrained targets have also helped to advance the use of risk assessments and risk management principles in MnDOT's investment decision-making. This TAMP supports the practice of identifying achievable, fiscally constrained outcomes as part of MnDOT's planning processes. However, it also clarifies MnDOT's terminology around targets and other types of performance outcomes in order to avoid confusion about what MnDOT is ultimately trying to accomplish.

The following terms differentiate between desired outcomes, outcomes associated with a fiscally constrained plan or budget, and forecasted outcomes based on predictive modeling.

- **Targets** reflect desired outcomes. Meeting a target constitutes the achievement of a performance goal. The purpose of targets is to evaluate system performance, identify performance-based needs, and guide strategic planning decisions. MnDOT may plan to meet or not meet targets based on funding levels and tradeoff decisions.

  Targets can be stated as fixed benchmarks against which MnDOT evaluates past, present and future performance. Fixed benchmarks are typically used to describe desired outcomes in performance areas where MnDOT has a high degree of control, such as ride quality or pavement condition. Targets can also be year specific. Year specific targets are trend-based and may change over time. They are typically used to evaluate the anticipated contribution of a program or set of planned investments.

- **Plan outcomes** describe future performance outcomes consistent with MnDOT's financially constrained spending priorities. These outcomes, which are established in conjunction with plan updates, are used to allocate resources, develop programs, and plan specific investments. Plan outcomes are stated in terms of the year in which MnDOT plans to achieve them, typically at the completion of a plan's time horizon.

  The terms target and plan outcome are not mutually exclusive. MnDOT may choose to fully fund a target, in which case the target and plan outcome are the same. In performance areas where targets and plan outcomes diverge due to insufficient resources, MnDOT uses the target to communicate need, while managing its program and maintenance activities to the plan outcome.

- **Expected outcomes** reflect predictive modeling of future performance. All plan outcomes begin as expected outcomes. However, expected outcomes often diverge from plan outcomes as plans age and as new information becomes available. MnDOT contrasts expected outcomes with plan outcomes at regular intervals to evaluate how successfully it is executing its plans/budgets. These evaluations promote accountability. Evaluations that show a significant discrepancy between a planned and an expected outcome can trigger a course correction in the form of new spending priorities or a revised strategy.

This terminology replaces the language used in MnSHIP to describe performance outcomes. Going forward, MnDOT will use **target** to denote desired outcomes. The term **plan outcome** will be used to identify outcomes to which MnDOT is managing. As long as MnDOT is on pace to achieve plan outcomes, the gap between a target and an **expected outcome** will be used to demonstrate need; however, it will not be used as a justification for reallocating resources within existing constraints. **Figure 3-3** summarizes the key characteristics of targets, plan outcomes and expected outcomes, as explained above.

Figure 3-3: Types of Performance Outcomes – Key Characteristics

TERM	MEANING	USE	HOW IS IT ESTABLISHED?	HOW OFTEN IS IT USED?
Target	Outcome consistent with agency goals and traveler expectations	• Communicate desired outcome • Evaluate performance • Identify investment needs	Approved by senior leadership; guided by agency policies and public planning process	Less than once per planning cycle
Plan Outcome	Outcome consistent with fiscal constraint / spending priorities	• Communicate spending priorities • Develop / manage programs • Select investments	Established concurrently with the adoption of investment plans	Once per planning cycle
Expected Outcome	Forecasted outcome based on predictive modeling	• Monitor plan implementation • Promote accountability / initiate corrective action	Generated by expert offices based updated performance information and planned improvements	Annually

Chapter 7 and **Chapter 8** provide an expanded narrative on targets, plan outcomes and expected outcomes for each of the asset categories covered in this TAMP.

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Chapter 4

ASSET INVENTORY AND CONDITION

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ASSET INVENTORY AND CONDITION

Overview

Minnesota's state highway system includes the National Highway System and other important roads. The importance of the state highway system is demonstrated by its use. Although it comprises just 8.5 percent of Minnesota's total roadway system mileage, it carries almost 60 percent of the miles traveled statewide, including the majority of freight being moved by road within the state.

Minnesota's state highway system is comprised of approximately 14,000 roadway miles and 4,500 bridges. Collectively, the replacement value of these assets is roughly $40 billion. In addition to roadways and bridges, MnDOT is responsible for maintaining many other transportation assets as shown in **Figure 4-1**. MnDOT has a direct ownership role in hydraulic infrastructure, roadside asset and traffic infrastructure within the right of way. For the majority of the multimodal assets, MnDOT manages grants monies or conveys or transfers ownership of property. Given significant investment in these assets, continuing demands on the system, and increased fiscal constraints on available funding for managing the system, it is imperative that MnDOT continues to identify ways to improve its transportation asset management practices, which ensure a strategic and systematic process for managing asset performance.

Figure 4-1: Examples of Assets Managed by MnDOT

HYDRAULIC INFRASTRUCTURE
• Culverts
• Stormwater Systems
• Tunnels
TRAFFIC INFRASTRUCTURE
• Intelligent Transportation System (ITS) Assets
• Sensor Systems
• Traffic Signals
• Sign Structures
• Sign Panels

ROADSIDE ASSETS
• Pavement Marking, Striping
• Curb and Gutter
• Guardrails
• Fence, Barriers, Impact Attenuators
• Noise Walls
• Slopes, Embankments, Retaining Walls
• Rest Areas
• Weigh Stations
• Lighting Structures
MULTIMODAL ASSETS
• Americans with Disabilities Act (ADA) Features
• Bicycle & Pedestrian Facilities
• Transit (Bus and Rail)
• Freight
• Airports
• Ports and Waterways

Factors Influencing Asset Condition and Performance

The advanced age of Minnesota's state highway assets is one of the primary challenges facing MnDOT today. **Figure 4-2** illustrates the age profile of state highway pavements. It shows that approximately half of the network is more than 50 years old. The major spike of activity in the late 1940s through the 1950s is the advent of the Interstate System, which also included the structural enhancement of much of the non-Interstate highway system. This activity began to taper off in the 1960s as much of the rural interstate was completed. Several gaps in the interstate system were completed through the mid-1980s. **Figure 4-3** shows a similar age profile and spikes for state highway bridges, with approximately 40 percent of MnDOT's bridges built before the early 1970's. The application of a variety of maintenance and rehabilitation treatments has helped MnDOT considerably extend the service life of pavements and bridges although not always at the lowest life-cycle cost. The ability to predict and monitor deterioration is a key factor in effectively managing these assets over their life-cycles.

Life-cycle cost considerations (the subject of **Chapter 6**) recognize that the cost of maintaining pavements and bridges in serviceable condition increases as they age. This dynamic, in conjunction with limited resources, makes it more difficult to meet pavement and bridge condition targets while also limiting MnDOT's ability to invest in other performance areas.

Figure 4-2: Age Profile of State Highway Pavements

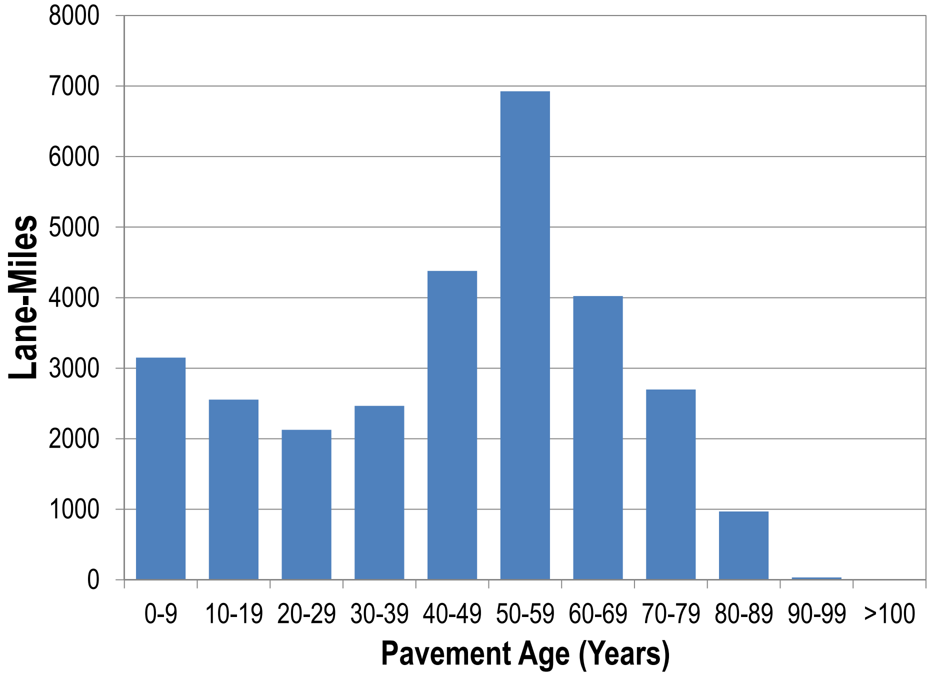
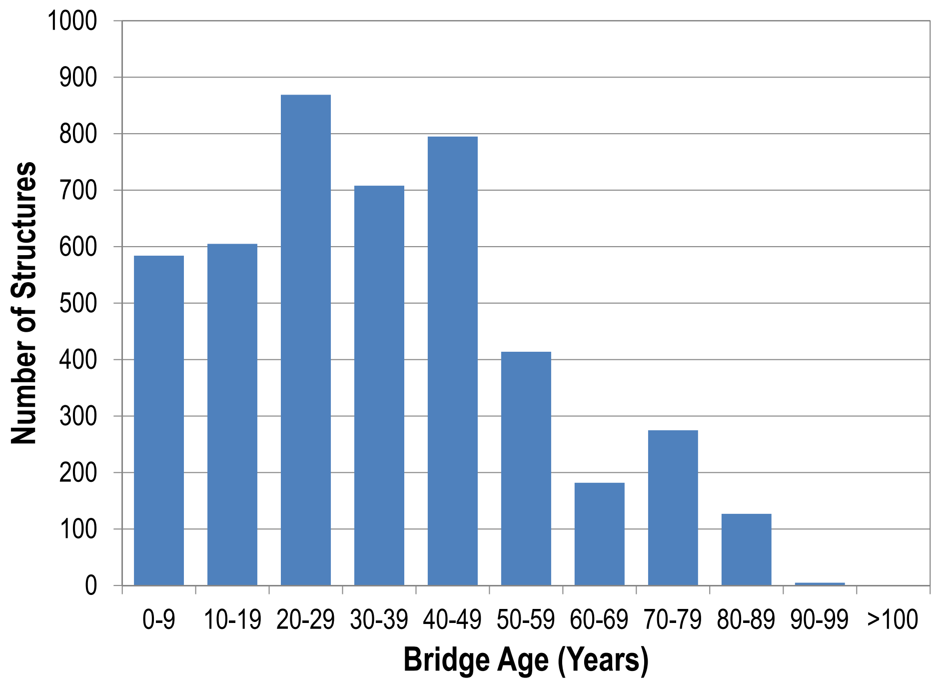


Figure 4-3: Age Profile of State Highway Bridges



In addition to age, the condition of state highway assets is influenced by type of construction, climate conditions and traffic usage. Significant flood events in 2010 and 2012 in Southeast and Northeast Minnesota caused widespread damage and highlighted the need to better understand flooding impacts on asset condition. MnDOT is currently participating in an FHWA Flash Flood Vulnerability and Adaptation Assessment Pilot Project that will help MnDOT and other state DOTs better understand the process for incorporating climate change in asset management planning. Some of the main factors influencing the condition of the assets included in the TAMP are highlighted in **Figure 4-4**.

Figure 4-4: Significant Factors Influencing Asset Conditions

PAVEMENTS	BRIDGES	HIGHWAY CULVERTS & STORMWATER TUNNELS	OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES
• Pavement type • Traffic volumes • Traffic weight • Environmental factors • Material properties • Type of underlying material • Maintenance frequency • Construction quality	• Bridge type • Usage of deicing chemicals • Presence of water • Traffic volumes • Traffic weight • Environmental factors • Material properties • Maintenance frequency • Construction quality	• Material type • Support of underlying foundation • Shape and geometry of culvert • Culvert thickness and condition • Installation quality • Pressurization and maintenance frequency	• Fabrication quality • Installation quality • Material type • Traffic hits • Strong winds • Fatigue

A key to managing assets effectively is the ability to forecast changes in condition over time for each type of asset. MnDOT has developed sophisticated deterioration models for pavements. These models are used in the pavement management system to predict future conditions under different treatment scenarios. Although deterioration models are not currently available for the other asset categories included in the TAMP, planned enhancements to MnDOT's bridge management program include adding modeling capabilities. For bridges, highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures, MnDOT experts provided input to develop the projections that inform the life-cycle costing discussed in **Chapter 6: Life-Cycle Costs Considerations**.

Asset Inventory and Condition Summary

The fundamental philosophy and principles of asset management apply to all infrastructure assets maintained by MnDOT. This first edition of the TAMP addresses the following selected asset categories: pavements, bridges, highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures. Additional asset categories will be added in future TAMPs. The Moving Ahead for Progress in the 21st Century Act (MAP-21) transportation authorization bill requires a TAMP for all pavement and bridges on the National Highway System. MnDOT's TAMP exceeds these requirements.

The information needed to develop the TAMP for pavements and bridges was, for the most part, readily available in MnDOT's pavement and bridge management systems. For other asset categories, data were less complete or accessible. For instance, condition inspections were performed less consistently on deep stormwater tunnels, overhead sign structures, and high-mast light tower structures. As a result, data on maintenance history, asset condition, and deterioration rates were less than optimal for these assets. MnDOT is using this opportunity to assess the maturity level of the maintenance and management of these assets, to identify process improvements that will help manage them more effectively, and to apply these principles to other MnDOT asset groups.

Figure 4-5, **Figure 4-6**, **Figure 4-7**, and **Figure 4-8** comprise "folios" summarizing much of the available information on the **inventory and estimated replacement value** of each asset category, along with **data collection, management, and reporting practices** and **current condition, recommended targets, and investment levels** (recommended targets reflect changes discussed in **Chapter 2** and **Chapter 7**; investment levels are discussed in **Chapter 8**). This information was provided by Work Groups of MnDOT technical experts specially convened around each of the asset categories considered in this TAMP. It was then vetted by the larger TAMP project Steering Committee before inclusion in this plan.

A roadway mile is an entire segment of highway (all lanes), one mile in length.

A lane mile is a section of pavement with an area one lane-width wide by one mile long.

Both measures are used to calculate various pavement needs and costs.

Pavement replacement value is estimated at $1 million per lane mile. This is based on an average for Minnesota's entire trunk highway network.

Figure 4-5: Pavement Folio

PAVEMENTS

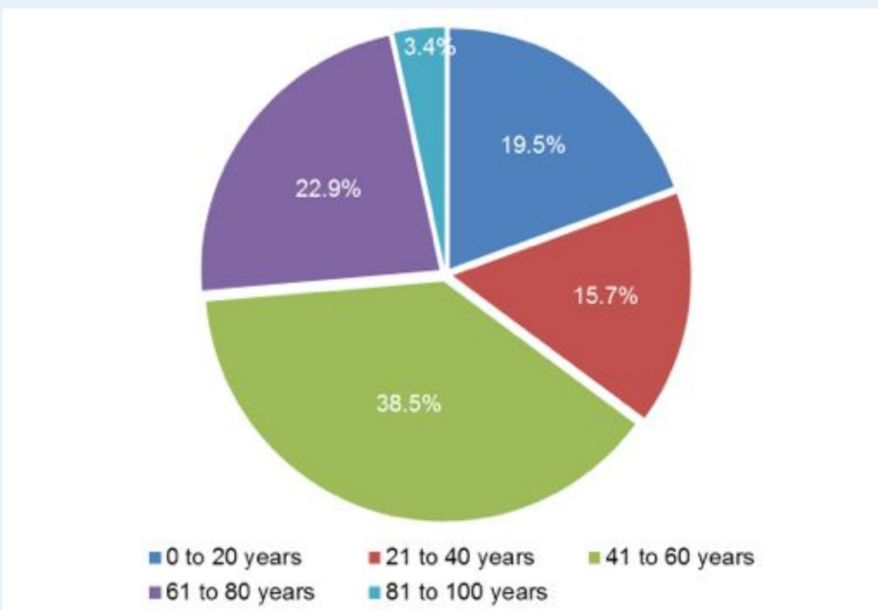
Pavements are a critical part of MnDOT's transportation network, providing mobility and access to a wide range of users. MnDOT's system consists of two types of pavements: flexible and rigid. Flexible pavements are often referred to as bituminous or black top, while rigid is commonly referred to as concrete. The state system consists of Interstates (e.g. I-94, I-35), non-Interstate NHS (e.g. Hwy 14, Hwy 169), and non-NHS highways (e.g. Hwy 75, Hwy 218). The entire state highway system is considered in all of the analyses (life-cycle cost analysis, risk management, financial plan and investment strategies) performed as a part of this TAMP.

INVENTORY AND REPLACEMENT VALUE

SYSTEM / FUNCTIONAL CLASSIFICATION	FLEXIBLE ROADWAY MILES	RIGID ROADWAY MILES	TOTAL ROADWAY MILES	TOTAL LANE-MILES	CURRENT REPLACEMENT VALUE
Interstate	925	896	1,821	4,036	$4.04 billion
Non-Interstate NHS	4,660	1,114	5,774	11,759	$11.76 billion
Non-NHS	6,569	167	6,736	13,567	$13.57 billion
TOTAL	**12,154**	**2,177**	**14,331**	**29,362**	**$29.36 billion**

Notes: Interstate and Non-Interstate NHS do not include locally-owned NHS roadways (232 roadway miles); current replacement value based on $1 million per lane-mile

PAVEMENT AGE PROFILE (BY LANE-MILE)



DATA COLLECTION, MANAGEMENT, AND REPORTING PRACTICES

Data Collection:

- Automated data collection performed annually on all state highways
- Ride condition and surface distresses collected
- Shoulders and ramps not surveyed
- Office of Road Research responsible for data collection

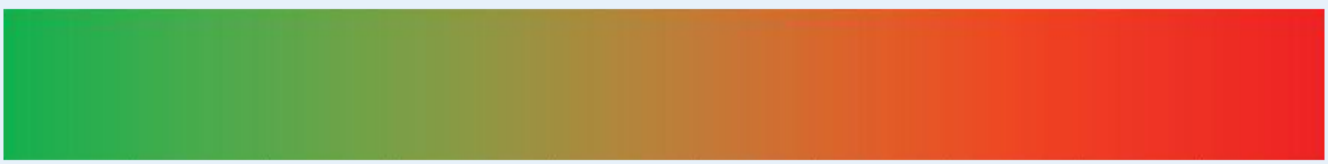
Data Management:

- Highway Pavement Management Application (HPMA) used to managed inventory and condition data
- Pavement condition deterioration models, project selection handled through HPMA

Data Reporting:

- Pavement condition report published annually by MnDOT Pavement Management Unit
- Data available on MnDOT's website

CONDITION RATING SCALE BASED ON RIDE QUALITY INDEX (RQI)



Good: 3.0 < RQI ≤ 5.0	Fair: 2.0 < RQI ≤ 3.0	Poor: RQI ≤ 2.0

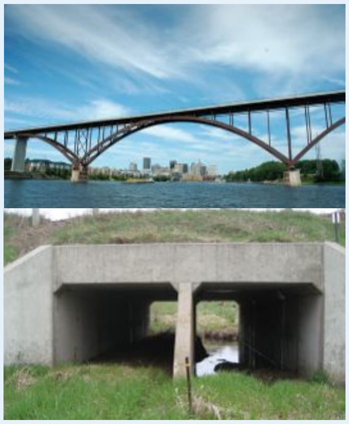
CONDITION, TARGETS, AND 10-YEAR INVESTMENT LEVELS

SYSTEM	2012 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS IN 2023
Interstate	2.4%	≤ 2%	$392 million
Non-Interstate NHS	4.3%	≤ 4%	$1.1 billion
Non-NHS	7.5%	≤ 10%	$1.4 billion
TOTAL	**NA**	**NA**	**$2.9 billion**

Note: Interstate and non-interstate NHS do not include locally-owned NHS roadways (232 roadway miles)

Figure 4-6: Bridge Folio

BRIDGES (INCLUDES LARGE CULVERTS)



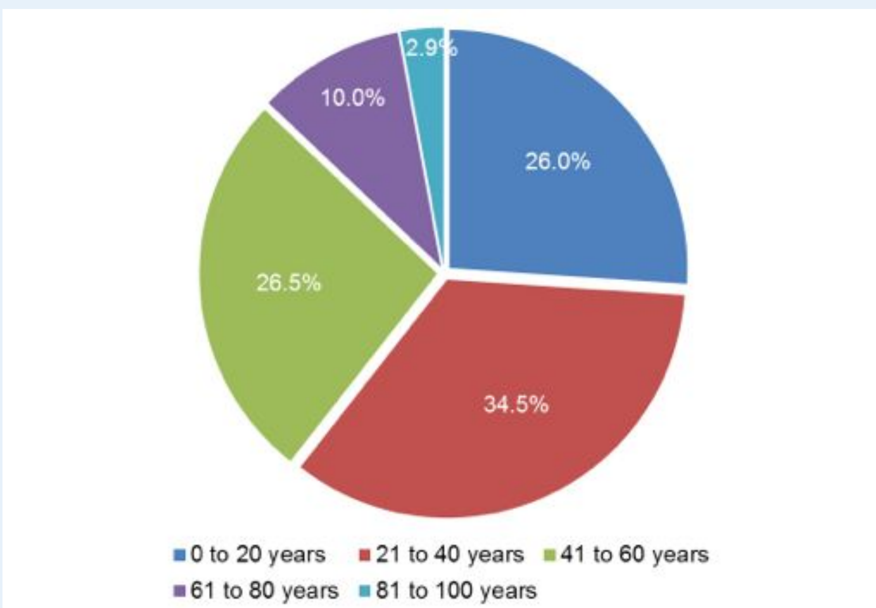
Bridges are large, complex, and expensive assets that are custom-designed and built to satisfy a wide variety of requirements. Large culverts (typically greater than 10 ft.) are also included in the bridge inventory. Analysis results related to bridges and large culverts presented in this TAMP (life-cycle cost analysis, risk management, financial plans and investment strategies) are limited to the National Highway System (NHS) inventory.

INVENTORY AND REPLACEMENT VALUE

SYSTEM / FUNCTIONAL CLASSIFICATION	COUNT	BRIDGE AREA (SQ. FT.)	CURRENT REPLACEMENT VALUE
Interstate	755	13,161,229	$1.9 billion
Non-Interstate NHS	1,196	13,483,129	$2.0 billion
Non-NHS	2,592	18,881,065	$2.7 billion
TOTAL (State Highway)	**4,543**	**45,525,423**	**$6.6 billion**

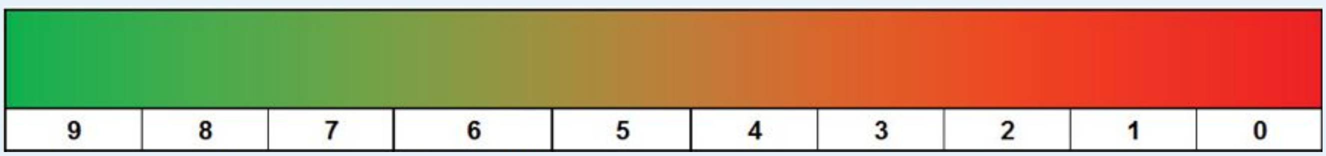
Notes: Interstate and Non-Interstate NHS do not include locally-owned NHS bridges (23); replacement values range from $145/sq. ft. to $225/sq. ft. depending on bridge type

BRIDGE AGE PROFILE (BY NUMBER OF BRIDGES)



DATA COLLECTION, MANAGEMENT, AND REPORTING PRACTICES
Data Collection: • Data collection based on National Bridge Inspection Standards (NBIS), AASHTO, and MnDOT requirements • Most bridges inspected annually in Minnesota (some more or less frequently based on inspection results) • Districts perform/supervise inspections with some centralized management and Quality Assurance / Quality Control of data collected
Data Management: • Pontis / Bridge Replacement and Improvement Management (BRIM) tools used to store and analyze data • Structure Information Management System (SIMS) used to enter, submit, and manage inspection data
Data Reporting: • Bridge inspection and inventory reports available through MnDOT's website

CONDITION RATING SCALE (BASED ON NBIS RATING SCALE)



Good: 7-9	Satisfactory: 6	Fair: 5	Poor: 0-4

CONDITION, TARGETS, AND 10-YEAR INVESTMENT LEVELS			
SYSTEM	2012 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS IN 2023
Interstate and Non-Interstate NHS	4.7%	≤ 2%	$1.10 billion
Non-NHS	2.1%	≤ 8%	$430 million
TOTAL	**4.3%**	**NA**	**$1.53 billion**

Note: Interstate and Non-Interstate NHS do not include locally-owned NHS bridges (23)

Figure 4-7: Hydraulic Infrastructure Folio

HYDRAULIC INFRASTRUCTURE (HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS)

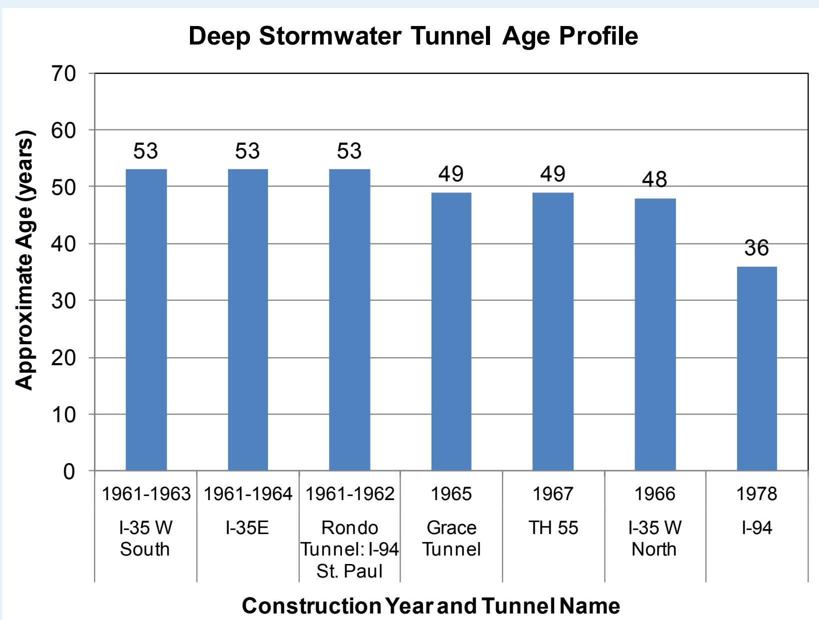
Hydraulic infrastructure, including highway culverts (diameter greater than 10 feet) and deep storm water tunnels, helps MnDOT effectively manage water flows throughout the state. Highway culverts convey surface water runoff under and adjacent to the state highway system. Deep stormwater tunnels are located in the Twin Cities Metropolitan Area, collect stormwater runoff (e.g. runoff from major highways and surrounding community), and are approximately 50-100 feet below the surface. All state highway system culverts and deep stormwater tunnels are considered in all of the analyses (life-cycle cost analysis, risk management, financial plans and investment strategies) performed as a part of this TAMP.

INVENTORY AND REPLACEMENT VALUE

ASSET TYPE	COUNT / UNIT	CURRENT REPLACEMENT VALUE
Highway Culverts	47,157 (number)	$1.7 billion
Deep Stormwater Tunnels	69,272 linear feet (7 tunnels, 50 segments)	Approximately $300 million

Note: Replacement value for centerline highway culverts based on $798 per foot., assuming average culvert length of 45 feet; replacement value for tunnels based on approximate estimate provided by hydraulic infrastructure Work Group

HYDRAULIC INFRASTRUCTURE AGE PROFILES



Insufficient Data for Highway Culvert Age Profile

DATA COLLECTION, MANAGEMENT, AND REPORTING PRACTICES
Data Collection: • Condition inspections performed in-house or through contract • Data collection frequency varies: 1 to 6 years for culverts; 2 to 5 years for deep stormwater tunnels • Culverts managed by MnDOT districts: Maintenance or Hydraulics / Water Resources Engineering (WRE) Division • Tunnels managed by Metro District WRE
Data Management: • HydInfra information application used to manage inventory, inspection, and maintenance activities
Data Reporting: • Condition ratings extracted from HydInfra system for internal reporting purposes

CONDITION RATING SCALE (BASED ON HYDINFRA RATING SCALE)				
Not Rated: 0	Like New: 1	Fair: 2	Poor: 3	Very Poor: 4

CONDITION, TARGETS, AND 10-YEAR INVESTMENT LEVELS			
SYSTEM	2012 CONDITION	TARGETS	INVESTMENT REQUIRED TO ACHIEVE TARGETS IN 2023
Centerline Highway Culverts	10% Poor; 6% Very Poor	≤ 8% Poor; ≤ 3% Very Poor	$400 million
Deep Stormwater Tunnel	39% Poor; 14% Very Poor	≤ 8% Poor; ≤ 3% Very Poor	$35 million (condition) + $1.6 million (inspection)

Figure 4-8: Other Traffic Structures Folio

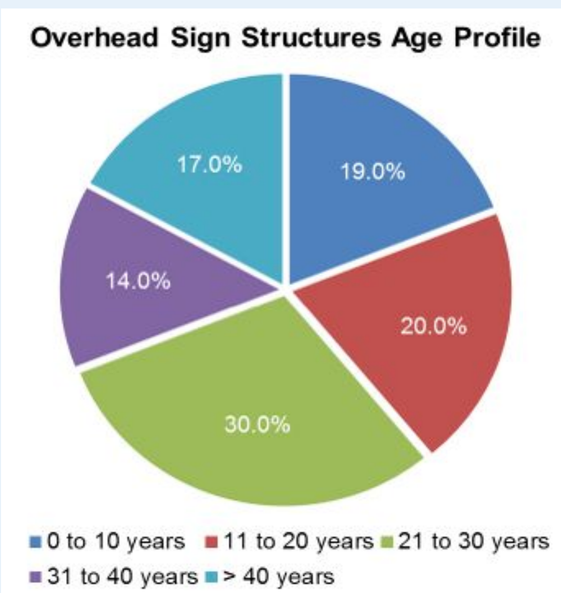
OTHER TRAFFIC STRUCTURES: OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES

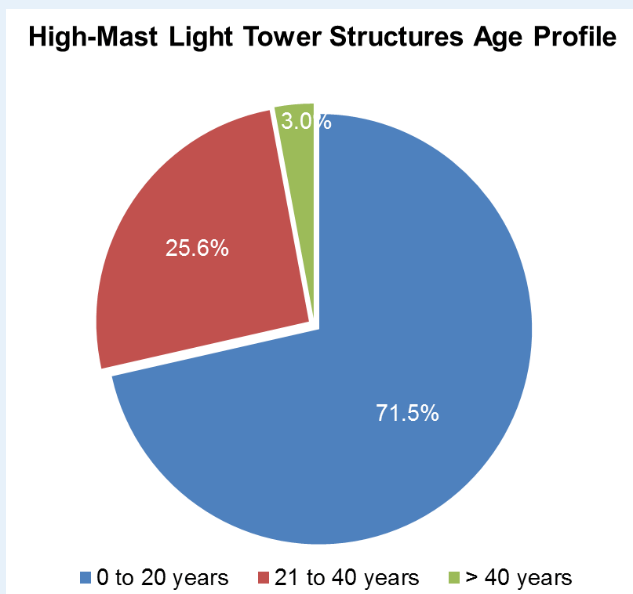
Other traffic structures included in this TAMP are overhead sign structures and high-mast light tower structures. Overhead sign structures include various types of span and cantilever structures, designed to support signs requiring vertical clearance for vehicles to pass underneath. High-mast light tower structures are tall poles, approximately 100 feet in height, which support 3-5 large lamps. The analysis performed in this TAMP accounts only for structural condition; other functional and operational requirements (e.g. sign retroreflectivity, bulb replacement) are not considered.

INVENTORY AND REPLACEMENT VALUE		
SYSTEM / FUNCTIONAL CLASSIFICATION	COUNT	CURRENT REPLACEMENT VALUE
Overhead Sign Structures	2,359	$200 million
High-Mast Light Tower Structures	476	$19 million

Note: Current Replacement Value is based on $85,000 per overhead sign structure and $40,000 per high-mast light tower structure

OTHER TRAFFIC STRUCTURES AGE PROFILES (BY NUMBER OF STRUCTURES)





DATA COLLECTION, MANAGEMENT, AND REPORTING PRACTICES
Data Collection: • Condition inspections performed in-house or via contract • Data collection typically on a five-year cycle • Data collection managed by the Maintenance / Traffic Division
Data Management: • Overhead sign structure data stored in a spreadsheet or on paper • High-mast light tower structure data stored in AFMS and in an Access database
Data Reporting: • Condition ratings extracted from rating spreadsheet for internal reporting purposes

CONDITION RATING SCALE (BASED ON NBI RATING SCALE)

Good: 7-9	Satisfactory: 6	Fair: 5	Poor: 4	Very Poor: 0-3

CONDITION, TARGETS, AND 10-YEAR INVESTMENT LEVELS

SYSTEM	2012 CONDITION	TARGETS	INVESTMENT REQUIRED TO ACHIEVE TARGETS IN 2023
Overhead Sign Structures	6% Poor; 8% Very Poor	≤ 4% Poor; ≤ 2% Very Poor	$8 million
High-Mast Light Tower Structures	6% Poor; 15% Very Poor	TBD	TBD

Note: MnDOT is in the process of developing a new rating system for high-mast light tower structures

Asset Value

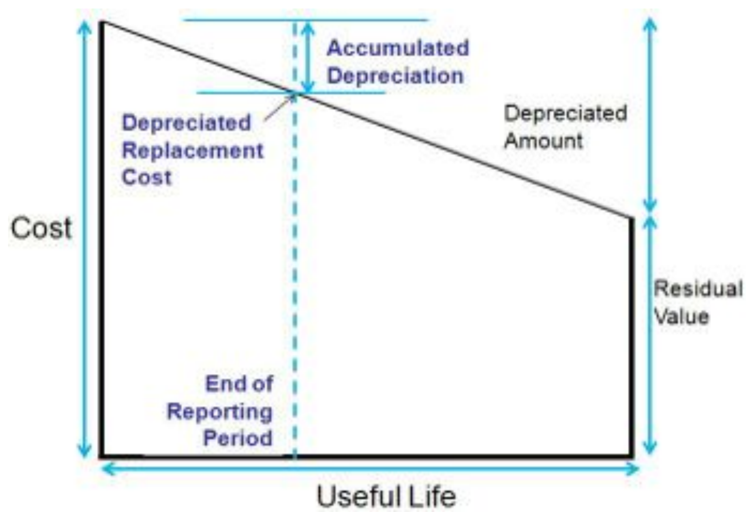
Transportation assets represent a significant investment - one that is crucial to the economic viability of the state. It is therefore important to preserve the value of transportation assets through a series of planned activities that extend their service lives for as long as possible. A summary of approximate current replacement values of the asset categories included in the TAMP is shown in **Figure 4-9**.

Figure 4-9: Summary of Current Replacement Value of Assets

STATE HIGHWAY SYSTEM ASSETS	CURRENT REPLACEMENT VALUE
Pavements	$29.4 billion
Bridges	$6.6 billion
Hydraulic Infrastructure (Highway Culverts and Deep Stormwater Tunnels)	$2.0 billion
Other Traffic Structures (Overhead Sign Structures and High-Mast Light Tower Structures)	$220 million
Total	**$38.2 billion**

As an asset ages, its value and functionality gradually declines. In accounting terms, this decrease in value is referred to as depreciation. Monitoring the change in asset value over time (illustrated in **Figure 4-10**) is one way of determining whether investment levels in transportation assets are financially sustainable. Stated simply, if an agency is not investing at least as much as its assets are depreciating each year, the assets are losing value and the program is not financially sustainable. The use of value to monitor financial sustainability is gaining momentum nationally. Therefore future MnDOT TAMPs may include a comparison between estimated asset depreciation and anticipated investment.

Figure 4-10: Illustration of the Concept of Asset Value Deterioration



Chapter 5

RISK MANAGEMENT ANALYSIS

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RISK MANAGEMENT ANALYSIS

Overview

Risk is frequently defined as the effect of uncertainty on objectives. When applied to the management of transportation assets, acknowledging and understanding risk can help a transportation agency more effectively plan for possible system and program disruptions and complications, mitigate potential consequences, and improve agency and infrastructure resiliency.

MnDOT understands the value of accounting for and managing risk and has been incorporating risk into both capital and highway operations planning, as well as into business planning for each of the agency's functional areas. Most recently, risk assessment has been formally incorporated into the Minnesota 20-year State Highway Investment Plan (MnSHIP), published in 2013, and played a prominent role during its development. MnDOT also produced an Enterprise Risk Management Framework and Guidance document in 2013, which "establishes the standards, processes and accountability structure used to identify, assess, prioritize and manage key risk exposures across the agency." Risk also factors into the most recent Statewide Highway Systems Operation Plan (HSOP), where it influences tradeoff discussions and funding prioritization.

This strong history with risk prompted MnDOT to take a somewhat unique approach to the Risk Management Analysis section of the TAMP. Because risk management is already integrated into most agency planning and management practices, it was recognized that focusing on "global" risks (e.g. natural events, operational hazards, aging assets) would be less beneficial than assessing and developing mitigation strategies for "undermanaged" risks – opportunities that exist for MnDOT to further improve its asset management processes.

Risk and Transportation

Like many transportation departments, MnDOT endeavors to provide the level of service demanded by the public at minimum cost. Unexpected events – including external hazards, economic disruptions, or insufficient understanding – can reduce the effectiveness of an agency in achieving its goals, however. **Figure 5-1** shows several examples of risks that are of particular concern to transportation agencies.

Figure 5-1: Key Transportation-Related Risk Factors

RISK FACTOR
Natural events (e.g. floods, storms, earth movement)
Operational hazards (e.g. vehicle and vessel collisions, failure or inadequacy of safety features, and construction incidents)
Asset ageing effects (e.g. steel fatigue or corrosion, advanced deterioration due to insufficient preservation or maintenance)
Adverse conditions in the economy (e.g. shortage of labor or materials, recession)
Staff errors or omissions in facility design, operations, or provision of services; or defective materials or equipment
Lack of up-to-date information about defects or deterioration, or insufficient understanding of deterioration processes and cost drivers

Consequences of such risks can include:

- Personal injury
- Loss of life
- Private property damage
- Infrastructure damage
- Traffic congestion
- Loss of access
- Loss of economic activity
- Harm to the environment
- Harm to public health
- Litigation and liability losses
- Resource waste
- Harm to agency reputation

Each of these can adversely affect the achievement of program goals and performance targets.

Some of these risk factors can be partially quantified by studying historical records, via active monitoring, or through quality assurance processes. Many significant risk factors, however, are prohibitively expensive or technologically impossible to measure. Even for factors that are difficult to measure, though, it is possible to adopt general risk management strategies, such as:

- Raising awareness of risks among staff and the public
- Adopting management strategies and techniques to avoid risks
- Prioritizing risk-prone assets for replacement
- Mitigating asset risks based on measurable characteristics that affect their resilience and exposure
- Working with partners and stakeholders on ways to reduce or to jointly manage risks

Risk at MnDOT

The principles of risk management have been adopted throughout the agency in recent years, from high level investment, management, or operations plans (MnSHIP, TAMP, HSOP) to individual asset management and programming systems and even research projects.

ENTERPRISE RISK MANAGEMENT (ERM)

To help guide the transition to formal and universal consideration of risk, MnDOT has implemented an ERM framework. The framework – illustrated in **Figure 5-2** – is an integral part of MnDOT's business processes, linking **strategic** risk assessments by senior executives to risks at the **business line** (program) level that affect products and services and at the **project** level that affect project objectives like scope, schedule, and cost. MnDOT created and now maintains a risk register to support the risk assessment processes, which reflects at any given time the current status of strategic and business line risks, including relevant performance objectives.

Figure 5-2: Levels of Risk Management MnDOT

MINNESOTA 20-YEAR STATE HIGHWAY INVESTMENT PLAN (MNSHIP)

Risk was a key factor considered during the 2013 MnSHIP process. Risk-based planning was central to its development, as MnDOT systematically identified the likelihood and impact of different risks to assess the tradeoffs associated with various investment mixes. The resulting comprehensive and dynamic document guides MnDOT's future investment planning.

As a result of changes in performance requirements, targets, and prioritization established by MAP-21, MnDOT also developed two programs – the Statewide Performance Program (SPP) and the District Risk Management Program (DRMP). By enhancing flexibility and collaboration with regional and local MnDOT staff, these programs help the agency effectively reallocate funding and address these changes. Further discussion of MnSHIP, the SPP, and the DRMP is found in **Chapter 8: Financial Plan and Investment Strategies**.

Figure 5-3 displays the capital investment risks categories considered in MnSHIP and the degree to which each is mitigated via the strategies outlined in the plan. Risks were not mitigated as well in years 11-20 (not relevant to the TAMP planning horizon and therefore not shown).

Figure 5-3: Investment Risk Mitigation in MnSHIP

KEY CAPITAL INVESTMENT RISKS	MITIGATED RISK THROUGH YEAR 10
GASB 34: pavement and bridge conditions deteriorate, jeopardizing state bond rating	*Partially mitigated.* MnDOT mitigates most of the risk through its investment priorities
Federal policy: failure to achieve MAP-21 performance targets on NHS reduces funding flexibility	*Adequately mitigated.* MnDOT mitigates most or all of the risk through its investment priorities
MnDOT Policy: misalignment with Vision and Statewide Multimodal Transportation Plan results in loss of public trust	*Partially mitigated.* MnDOT mitigates most of the risk through its investment priorities
Bridges: deferring bridge investments viewed as an unwise / unsafe strategy	*Adequately mitigated.* MnDOT mitigates most or all of the risk through its investment priorities
Responsiveness: rigid investment priorities limits ability to support local economic development and quality of life opportunities	*Partially mitigated.* MnDOT mitigates most of the risk through its investment priorities
Operations budget: untimely or reduced capital investment leads to unsustainable maintenance costs	*Partially mitigated.* MnDOT mitigates most of the risk through its investment priorities
Public outreach: investment inconsistent with MnSHIP public outreach results in loss of public trust	*Partially mitigated.* MnDOT mitigates most of the risk through its investment priorities

STATEWIDE HIGHWAY SYSTEMS OPERATION PLAN (HSOP)

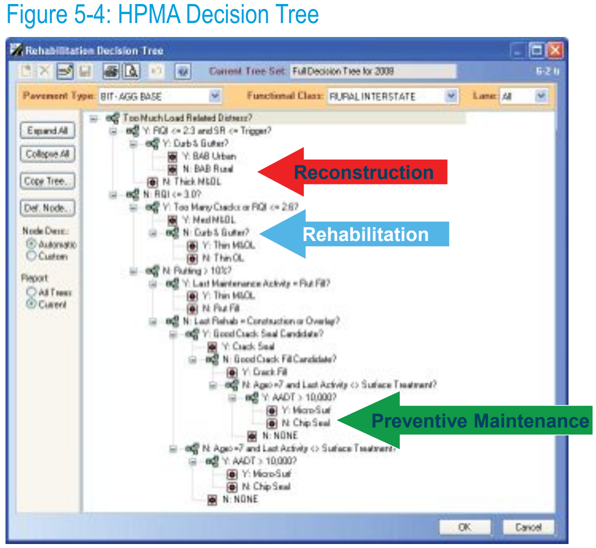
MnDOT's Statewide Highway Systems Operation Plan provides a framework for managing key operations and maintenance activities throughout the state, supports the agency's vision, and complements other planning efforts. It advocates performance-based planning and data-driven decision making for operations and maintenance. An Enterprise Risk Management assessment was completed as part of the HSOP and helped to identify, assess, manage, and communicate operations- and maintenance-related opportunities and threats. Assessments of risk are also driving factors for many operations and maintenance treatment decisions. With such a structure in place, MnDOT operations decision-makers and managers have a good baseline understanding of the current risk environment, a common language in operations, a risk inventory, and a risk-ranking methodology to prioritize risks within and across functions.

HIGHWAY PAVEMENT MANAGEMENT APPLICATION (HPMA)

Decisions about pavement management at MnDOT are made with the help of HPMA, which uses pavement condition data to forecast needs and optimize the combination of preservation and rehabilitation activities, in order to most effectively mitigate risk and achieve the best conditions possible, given funding constraints. The dynamic application allows for comparisons between a range of treatment option scenarios, from "Do Nothing" to "Full Reconstruction". This process is explained further in **Chapter 8: Financial Plan and Investment Strategies**.

The HPMA also helps MnDOT meet its GASB 34 minimum condition thresholds (see **Chapter 3**), thereby avoiding the risk of not doing so. Risks associated with the application were evaluated and addressed as part of risk exercises conducted in 2011, 2012, and 2013 and are identified in MnDOT's ERM risk register. A conceptual model of HPMA is shown in **Figure 5-4**.

Figure 5-4: HPMA Decision Tree



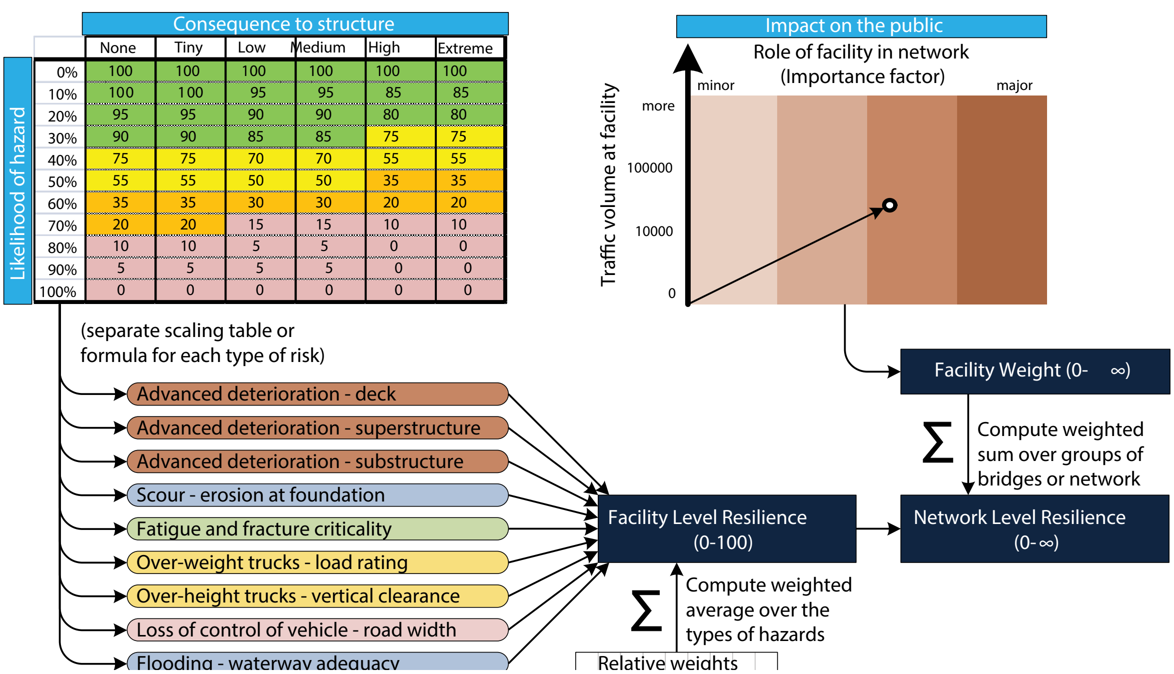
BRIDGE REPLACEMENT AND IMPROVEMENT MANAGEMENT (BRIM)

Many of MnDOT's asset-related risks are managed in whole or in part by established asset management processes, such as the BRIM program and the Highway Pavement Management Application (HPMA). BRIM is used by MnDOT to identify, classify, evaluate, and plan for a variety of quantifiable risks that apply to highway bridges. Hazards analyzed in BRIM include:

- Advanced deterioration of bridge decks, superstructures, and substructures
- Scour of riverbeds around bridge foundations
- Fracture criticality (possibility of bridge instability due to failure of only one element)
- Fatigue cracking
- Overload
- Collisions with over-height vehicles

Bridge characteristics related to each of these hazards are routinely updated in the MnDOT inventory. The information is used to prioritize necessary mitigation or replacement projects (illustrated in **Figure 5-5**). So far, MnDOT has not developed any network-level performance measures that can be used to track improvements in bridge resilience over time as a result of the BRIM analysis. This would be a logical next step to ensure effective implementation.

Figure 5-5: MnDOT Bridge Programming Risk Assessment



Likelihood of hazard	None	Tiny	Low	Medium	High	Extreme
0%	100	100	100	100	100	100
10%	100	100	95	95	85	85
20%	95	95	90	90	80	80
30%	90	90	85	85	75	75
40%	75	75	70	70	55	55
50%	55	55	50	50	35	35
60%	35	35	30	30	20	20
70%	20	20	15	15	10	10
80%	10	10	5	5	0	0
90%	5	5	5	5	0	0
100%	0	0	0	0	0	0

Source: NCHRP Report 706, Uses of Risk Management and Data Management to Support Target-Setting for Performance-Based Resource Allocation by Transportation Agencies (2011).

RESEARCH PROJECTS

Finally, the concept of risk also factors heavily into several past and current research projects at MnDOT. For instance, the agency was selected to participate in an FHWA Flash Flood Vulnerability and Adaptation Assessment Pilot Project that will help MnDOT (and other state DOTs) better understand the process for incorporating climate change in asset management planning. This project is currently underway and results, when ready, will help inform future asset management initiatives.

TAMP Risk Assessment

As detailed above, risk is an important part of MnDOT's practices. Nevertheless, the agency's approach to the risk section of the TAMP process began with a focus on "global" risks (e.g. natural events, operational hazards) and their effects on the asset, the public, and the agency. MnDOT engaged in an exercise to identify and prioritize strategic and business risks that could impact its ability to deliver the level of service expected by the public. Discussions were held with Work Groups of technical experts to describe and rate the major risks related to each asset category. **Figure 5-6** illustrates MnDOT's risk rating scale. In consultation with agency risk experts, each Work Group developed a series of risk statements and risk ratings, described potential mitigation strategies for each risk, and developed methods for estimating mitigation costs. This process was iterative, extending over three formal workshops, with opportunities between workshops to modify aspects of the product. Participants took advantage of the process to learn about the risks, assess the ability of existing information systems to quantify risks and costs, and reach consensus on priorities and approaches for future improvements.

Figure 5-6: Risk Rating Matrix

CONSEQUENCE RATINGS	LIKELIHOOD RATINGS AND RISK LEVELS				
	RATE	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
CATASTROPHIC	Medium	Medium	High	Extreme	Extreme
MAJOR	Low	Medium	Medium	High	High
MODERATE	Low	Medium	Medium	Medium	High
MINOR	Low	Low	Low	Medium	Medium
INSIGNIFICANT	Low	Low	Low	Low	Medium

Given MnDOT's previous efforts at incorporating risk throughout its planning and management, the risk identification and mitigation process also sparked a debate as to the merits of a more conventional risk approach. It was concluded that MnDOT's current practices were already mindful of many global risks, and that the agency (and the public it serves) would therefore benefit most if the risks addressed in the TAMP emphasized "undermanaged risks" – areas in which there were clear opportunities for improvement at MnDOT. After pivoting to this concept and eliminating well-managed risks, a final list of undermanaged risks – relating to data, maintenance, or inspections – and associated **risk mitigation strategies** was presented to the Steering Committee for prioritization. The steps taken during the risk and mitigation strategy identification, prioritization, and costing exercises are described in detail in the accompanying Technical Guide.

Figure 5-7 identifies the risk mitigation strategies, separated into three priority levels based on factors like need, ease of implementation, and ability to reduce the perceived risk. **Chapter 9: Implementation and Future Developments** provides more detail for these priorities, including purposes, responsible parties, expected timeframes, and estimated implementation costs.

Figure 5-7: Undermanaged Risk Mitigation Strategy Prioritization

PRIORITY LEVEL 1: HIGH PRIORITY, ADDRESS IMMEDIATELY
• Pavements: Annually track, monitor, and identify road segments that have been in Poor condition for more than five years, and consistently consider them when programming.
• Deep Stormwater Tunnels: Address the repairs needed on the existing South I-35W tunnel system.
• Deep Stormwater Tunnels: Investigate the likelihood and impact of deep stormwater tunnel system failure.
• Highway Culverts: Develop a thorough methodology for monitoring highway culvert performance.
• Overhead Sign Structures and High-Mast Light Tower Structures: Develop and adequately communicate construction specifications for overhead sign structures and high-mast light tower structures.
• Overhead Sign Structures and High-Mast Light Tower Structures: Track overhead sign structures and high-mast light tower structures in a Transportation Asset Management System (TAMS).

PRIORITY LEVEL 2: ADDRESS BASED ON ESTABLISHED PRIORITIES

- Pavements: Collect and evaluate performance data on ramps, auxiliary lanes, and frontage road pavements for the highway system in the Twin Cities Metro Area.
- Bridges: Augment investment in bridge maintenance modules and develop related measures and tools for reporting and analysis.
- Highway Culverts: Include highway culverts in MnDOT's TAMS.
- Deep Stormwater Tunnels: Place pressure transducers in deep stormwater tunnels with capacity issues.
- Deep Stormwater Tunnels: Incorporate the deep stormwater tunnel system into the bridge inventory.
- Overhead Sign Structures: Develop a policy requiring a five-year inspection frequency for overhead sign structures, as well as related inspection training programs and forms.

PRIORITY LEVEL 3: REVISIT WHEN ADDITIONAL FUNDING BECOMES AVAILABLE (AFTER ITEMS IN PRIORITY LEVELS 1 AND 2 HAVE BEEN ADDRESSED)

- Highway Culverts: Repair or replace highway culverts in accordance with recommendations from the TAMS.

Chapter 6

LIFE-CYCLE COST CONSIDERATIONS

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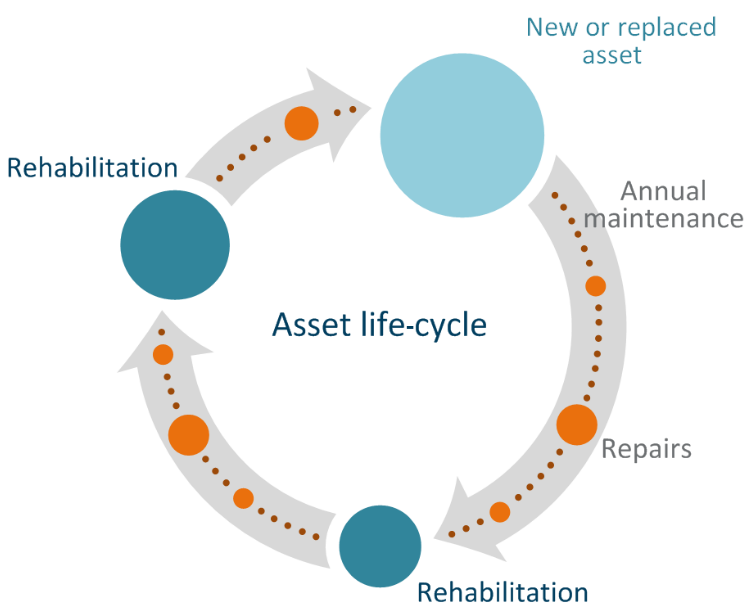
LIFE-CYCLE COST CONSIDERATIONS

Overview

Minnesota's transportation infrastructure is constantly under attack from the physical and chemical processes of deterioration, the damaging impact of floods and other hazards, and the normal wear-and-tear from use by thousands of cars and trucks. MnDOT and its partners work tirelessly to offset these effects and keep the state's valuable assets in service for as long as possible at minimum cost. Strong asset management practices help to minimize the total cost of managing transportation assets by focusing on all phases of an asset's life-cycle, each of which is shown in **Figure 6-1**.

Figure 6-1: Typical Asset Life-Cycle Phases



Because the service life of an asset can be lengthened through the timely application of maintenance and rehabilitation activities, MnDOT attempts to manage its transportation assets in a strategic and proactive way. This includes:

- Designing new facilities for durability and long life using state-of-the-art materials and methods
- Deploying well-trained maintenance personnel and advanced technology to apply needed maintenance actions at just the right times in the right places
- Anticipating future maintenance and rehabilitation costs that help defer the need for larger repair costs
- Taking advantage of preventive maintenance opportunities
- Minimizing the impact of work zones on the traveling public

The **life-cycle cost** of an asset includes costs associated with construction, inspection, maintenance, and disposal.

The **total cost of ownership** of an asset includes costs associated with life-cycle costs plus operations and other indirect costs.

MnDOT has been developing procedures and tools to forecast asset deterioration rates, determine the effectiveness of its maintenance and rehabilitation actions, and estimate the magnitude of future costs in an attempt to improve its ability to manage assets over their life-cycle. With performance-based procedures and tools in place, MnDOT can continue to improve its strategic decision processes to help further reduce agency costs over the long term.

Life-Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is an analytical technique used to assess the total cost of an asset. It takes into account all costs associated with construction, inspection, maintenance, and disposal. LCCA is especially useful when comparing alternate strategies that fulfill the same performance requirements but differ with respect to construction, maintenance and operational costs. These can be compared in terms of the total costs over the entire life-cycle of the asset.

Because they do not directly extend the life of an asset, annual operational investments (such as snow and ice removal, de-icing roads, and debris removal) have not been included in the LCCA. It should be noted, however, that operational expenses and other indirect costs form a large part of the overall cost of asset ownership. Collectively, construction, inspection, maintenance, operations, disposal, and other indirect costs associated with transportation assets comprise **total cost of ownership**. As an example, MnDOT spends between $50 and $85 million annually on snow and ice removal on roadways, depending on the severity of the winter. These operational requirements significantly impact the amount of funding available for asset maintenance and rehabilitation activities.

When a new road is built, the state commits not only to the initial construction costs, but also to the future costs of maintaining and operating that road. Over a long time period, future costs can be much greater than the initial cost. Therefore, it is important to manage the facilities as cost-effectively as possible over their entire service life.

Naturally, the owner of a facility would like to postpone future costs as much as possible. If costs can be postponed, the money saved can be redirected to other priorities. In life-cycle cost analysis, this preference is quantified as a discount rate. MnDOT's policy is to analyze all investments using a real annual discount rate which is currently 2.2 percent. The term "real" means that the effects of inflation are removed from the computation in order to make the cost tradeoffs easier to understand.

Although it is attractive to delay costs as much as possible and take advantage of the discount rate, there are limits. When maintenance is delayed, the condition of each asset worsens, eventually affecting the serviceability or even the safety of the infrastructure. Also, certain kinds of preventive maintenance actions are highly cost-effective, but only if performed at the optimal time. For example, painting a steel bridge at the right time is highly effective in prolonging its life. However, if painting is delayed, too much of the steel may already be rusted and painting is no longer as effective (or even possible). A much more expensive rehabilitation or replacement action is then required.

Additional terms used in LCCA are:

- **Analysis Period:** the time-frame over which the LCCA is performed
- **Life-Cycle Cost (in today's dollars):** the total cost to build, inspect, maintain, and dispose of an asset over the analysis period when the costs incurred in future years are converted to current dollars
- **Future Maintenance Costs as a Percent of Initial Investment:** the total future agency costs (including maintenance, rehabilitation, and inspection, but not operations costs) as a fraction of the initial construction cost of the asset (This value represents the future cost commitment that MnDOT makes for every dollar spent on a capital project.)

Theoretically, once a section of state highway is built, the agency is responsible for all future costs to keep that road in service, including the costs to reconstruct components of the road when they reach the end of their physical lives. However, because of discounting, costs in the far future have very little effect on any decisions made during the 10-year period covered by the TAMP. Forecasts of future deterioration and future needs become very unreliable if these predictions are extended too far into the future. In best practice, the analysis period of a life-cycle cost analysis should be as short as possible while still satisfying the following criteria:

- Long enough that further costs make no significant difference in the results.
- Long enough that at least the first complete asset replacement cycle is included.

The reason for the second criterion is that replacement costs are typically much larger than any other costs during an asset's life, so these costs can remain significant even if discounted over a relatively long period. A fair comparison of alternatives should therefore include at least the first replacement cycle for each of the alternatives being compared. The following analysis periods have been used in the LCCA:

- **Pavements:** A 70-year analysis period has been chosen to account for at least one complete reconstruction activity (which is estimated to occur 50 years after initial construction, on average) and compare that to a strategy in which reconstruction activity is delayed by a few years (due to short-term funding constraints) and less optimal treatments are selected.
- **Bridges, culverts, and deep stormwater tunnels:** These assets have lifespans that potentially extend for much longer than the 70-year scenarios analyzed for pavements. As a result, based on the second criterion, a 200-year life is used for this longer-lasting asset category.
- **Overhead sign structures and high-mast light tower structures:** An analysis period of 100 years was chosen based on a review of existing literature that suggests that the life of these structures, with routine maintenance and inspection, is expected to be at least 100 years.

The LCCA modeling strategies presented in the TAMP are summarized in **Figure 6-2**. The "Typical Strategy" reflects MnDOT's current practices for managing the assets and the "Worst-First" strategy involves complete replacement of the asset when it deteriorates to a Poor condition in the absence of preventive maintenance activities. The "Desired Strategy" (established only for pavements) corresponds to the strategy that MnDOT aspires to adopt in order to further reduce total life-cycle costs.

Figure 6-2: Life-Cycle Cost Analysis Modeling Strategies

ASSET	TYPICAL STRATEGY	WORST-FIRST STRATEGY	DESIRED STRATEGY
Pavements	• Delay need for reconstruction by applying a combination of surface treatments, crack sealing, and mill and overlays, depending on condition of pavement and available budget.	• Reconstruct a pavement as it deteriorates to Poor condition without routine preservation activities.	• Apply a major rehabilitation/ reconstruction activity at year 50, once the pavement has gone through a few preservation cycles and minor rehabilitation events.
Bridges and Large Culverts	• Perform repair and preventive maintenance on approximately two percent of bridges and large culverts; wash about 75 percent of bridges annually. • Perform limited repair actions, based on funding availability and judgment of inspectors and district bridge engineers.	• Replace entire bridge or large culvert structure as it deteriorates to a Poor condition without any preventive maintenance or repairs.	• Insufficient data
Highway Culverts	• Perform various maintenance actions on approximately two percent of culverts annually; flush each culvert once every 10 years. • Maintenance work performed based on judgment of inspectors.	• Replace culvert as it deteriorates to a Poor condition without any preventive maintenance or repairs.	• Insufficient data
Overhead Sign Structures and High-Mast Tower Lights	• Perform routine inspections after initial construction to determine maintenance needs. • Perform routine maintenance and major structural rehabilitation on an as-needed basis, as identified through inspections.	• Perform routine inspections after initial construction, but perform no maintenance. • Replace structure in a 40-year cycle (assuming deterioration to a condition when maintenance and rehabilitation are not expected to be effective).	• Insufficient data

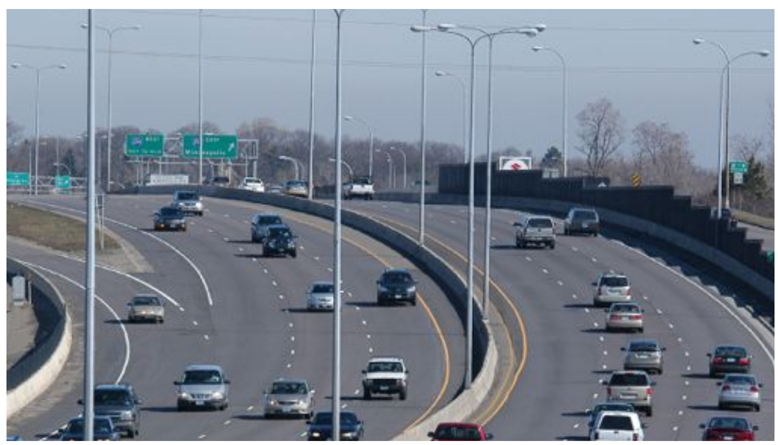
Notes: Typical Strategy reflects current MnDOT practices; Desired Strategy reflects optimal life-cycle strategy as described in MnDOT's Pavement Design Manual, there is not sufficient data currently available for other asset categories.

A key goal of a LCCA is to find the optimal level of maintenance where life-cycle costs are kept to an absolute minimum. This point may be known as the "happy medium," where maintenance expenditures are neither too frequent nor delayed too long. Typically, a well-maintained pavement or bridge, when maintained at a level that minimizes costs in the long-term, is kept in relatively good condition. **Over the life of a facility, well-timed maintenance is estimated to cut life-cycle costs roughly in half, compared to a policy where no maintenance is performed at all.**

PAVEMENTS

Roadways (see **Figure 6-3**) are a critical part of MnDOT's transportation network, providing mobility and access to a wide range of users. The roadway network not only contributes to the economy of the state, but also connects communities and provides access to schools, services, work, and places that matter most to Minnesotans. Pavements are a major part of this roadway network, providing a durable and safe traveling surface.

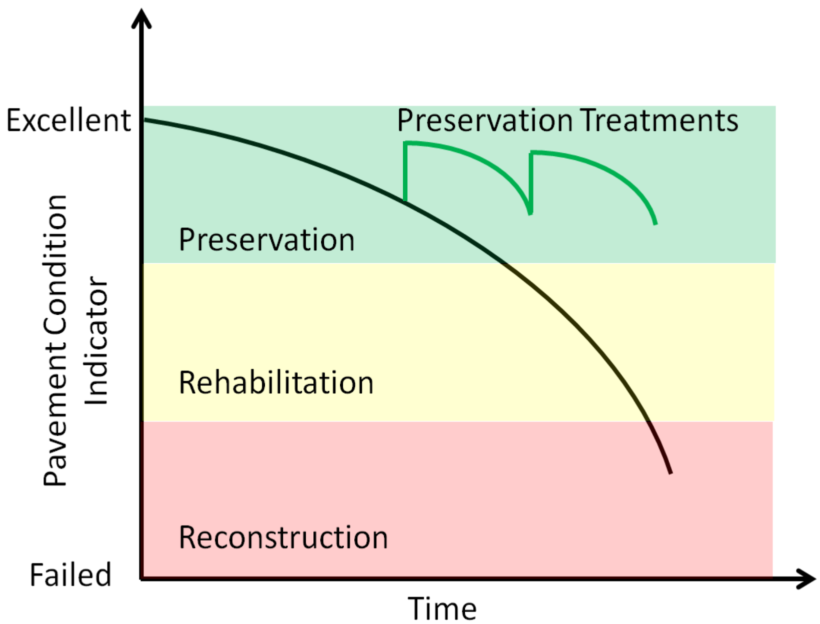
Figure 6-3: Typical Interstate Roadway in the Twin Cities Metro Area



As discussed in **Chapter 1** and **Chapter 4**, MnDOT maintains an inventory of more than 14,000 roadway-miles of pavements statewide, where the NHS pavements (Interstates, non-Interstate NHS, and locally-owned NHS) comprise over 7,800 roadway miles and the non-NHS pavements comprise almost 6,800 roadway miles of the total inventory. The current replacement values of NHS and non-NHS pavements are approximately $16 billion and $14 billion, respectively. These staggering costs demonstrate the need for a sound framework and methodological approach to manage these assets to the lowest life-cycle cost.

Pavements deteriorate over time due to environmental factors and traffic loading. As pavements age and start losing structural and/or functional capacity, they need to undergo maintenance and rehabilitation to restore them to the appropriate condition and provide a safe riding surface for the users. A typical pavement deterioration model demonstrating the impact of preservation is illustrated in **Figure 6-4**.

Figure 6-4: Typical Pavement Deterioration Model Illustrating Impact of Preservation

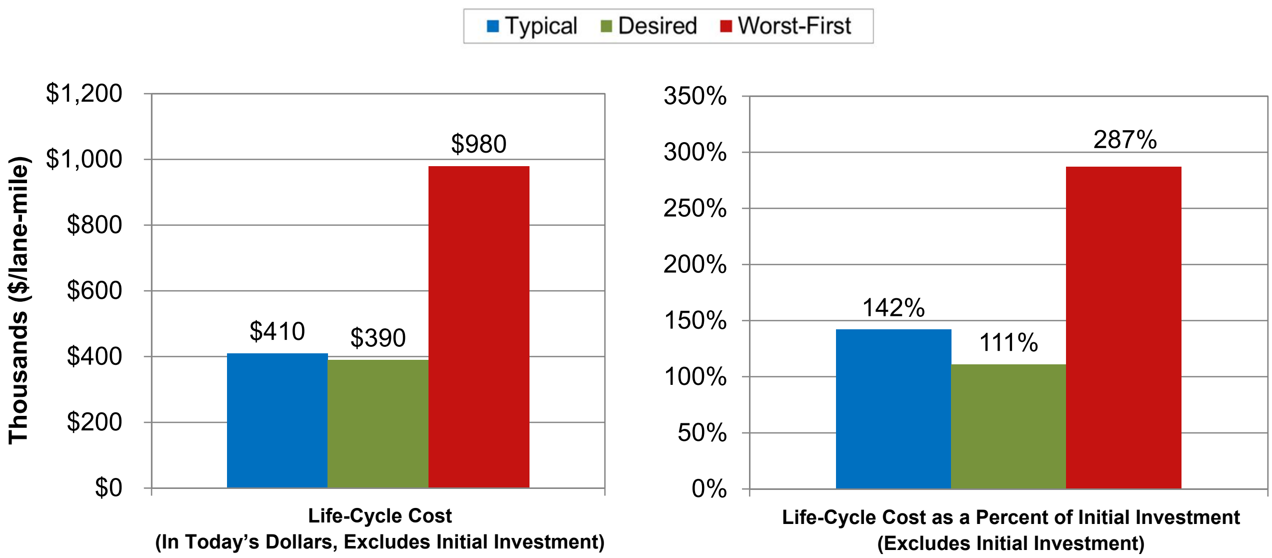


MnDOT has been actively involved in pavement preservation over the last decade to help sustain and improve the conditions of the existing pavement and delay the investments needed in major rehabilitation or reconstruction activities.

The typical preservation and rehabilitation treatments used by MnDOT on its asphalt-surfaced pavements include crack sealing, surface treatments (e.g. slurry seals, chip seals, and microsurfacing), full-depth reclamation, and asphalt mill and overlays. Typical preservation and rehabilitation treatments on concrete-surfaced pavements include joint resealing, partial depth repairs, minor/major concrete pavement repairs (e.g. dowel bar retrofit, diamond grinding, full-depth repairs), and unbonded overlays. While some treatments discussed above are applied primarily to extend the service life of the pavement and delay major rehabilitation/reconstruction activities, certain treatments are applied primarily to address safety issues (like friction loss or hydroplaning due to rutting in the wheel paths). The objective is to slow down the rate of deterioration and provide a smooth, durable, and safe roadway for the users at the lowest life-cycle cost.

The results of the life-cycle cost analysis highlighting the magnitude of differences in costs for each strategy are shown in **Figure 6-5**.

Figure 6-5: Summary of Life-Cycle Cost Analysis Results (Pavements)



MnDOT's current policy results in a savings of approximately 58 percent of future life-cycle costs when compared to the worst-first strategy. This is a savings of about $570,000 per lane-mile of pavement or approximately $17 billion over the entire inventory over the 70 year analysis period. Future costs (maintenance and capital) range from 1.1 (desired) to 2.9 (worst-first) times the initial cost of a capital project, depending on the treatment strategy used.

The results of the LCCA show the cost-effectiveness of the preservation strategy used by MnDOT to manage the pavements on the state highway system. The slightly higher life-cycle costs that MnDOT is incurring through its "typical" management strategy when compared to the "desired" strategy is the result of the need to balance investments between competing priorities (e.g., meeting state/federal targets, higher level of investment needed on some critical pavement sections in Poor condition).

BRIDGES AND LARGE CULVERTS

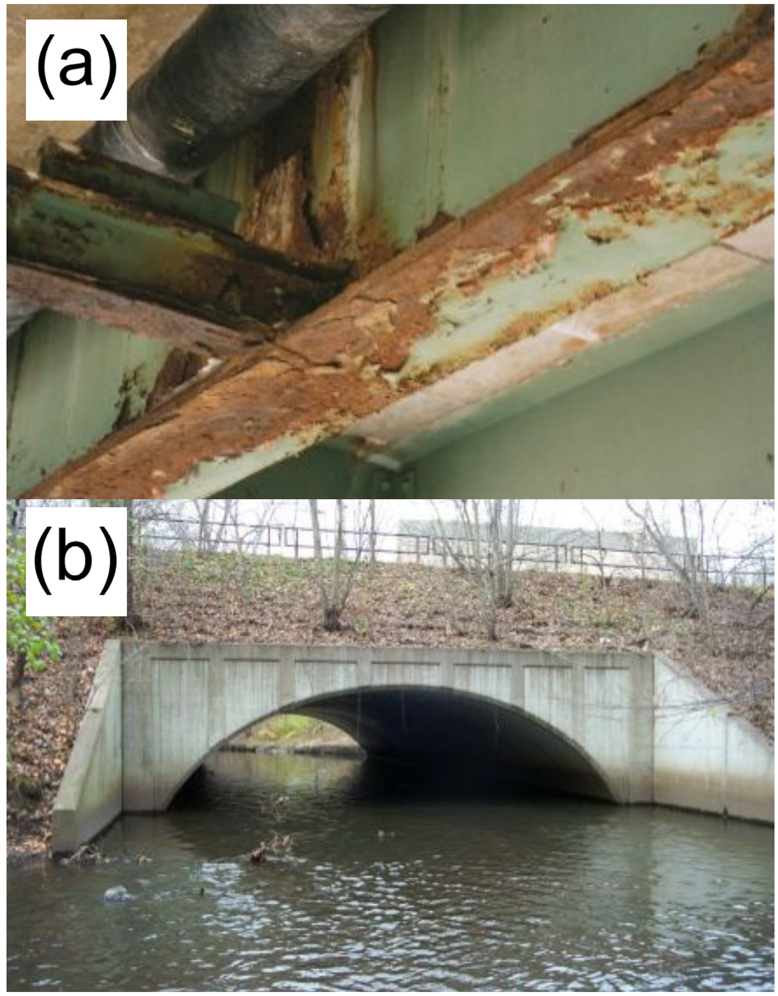
Bridges are large, complex, and expensive assets that are custom-designed and built to satisfy a wide variety of requirements. All culverts of at least 10 feet in diameter (and some important smaller culverts) are inspected and managed as bridges. The bridges addressed in this TAMP (NHS, non-NHS, large culverts) have a replacement value of approximately $4 billion. Although bridges and large culverts are managed using the same system, the LCCA was performed separately because deterioration rates, treatment costs and types are different.

Consistent with Federal and industry specifications, MnDOT performs a detailed inspection on all of its bridges on a periodic basis, usually at two year intervals as outlined in the MnDOT Bridge Inspection Best Practices Manual. Preventive maintenance actions – flushing, crack sealing, painting, etc. – are typically performed according to an assigned frequency, which is determined using criteria such as the activity performed, bridge age and type, condition, and traffic volume and control. Most bridges are flushed annually to remove corrosive salts from the bridge deck and other elements like joints, drains, bearing seats, and superstructure elements (e.g. beam ends, lower chord members). Staffing, funding, work zone traffic control limitations on high-volume bridges (typically on Interstate Highways), and other system priorities constrain MnDOT from being able to flush all bridges annually. Reactive maintenance actions, like patching, are performed based on conditions noted in the inspections.

Most bridges in the inventory are designed to last 50 years, but MnDOT experience has shown that many of them can last much longer if well-maintained. Newer bridges are designed for a 75 year life using more advanced materials and construction methods.

Bridges and culverts deteriorate over time. In particular, steel is strong, light, and inexpensive, but is prone to corrosion. Paint and concrete cover the steel and protect it from corrosion [see **Figure 6-6 (a)**]. But paint and concrete are often exposed to weather, traffic, erosion, animals, chemicals, and collisions, and therefore require regular care. These materials can also crack as they age, thus weakening their structural strength and allowing corrosive water and chemicals to penetrate the materials, worsening deterioration. Certain bridge materials, especially timber may also be subject to attack by insects and micro-organisms.

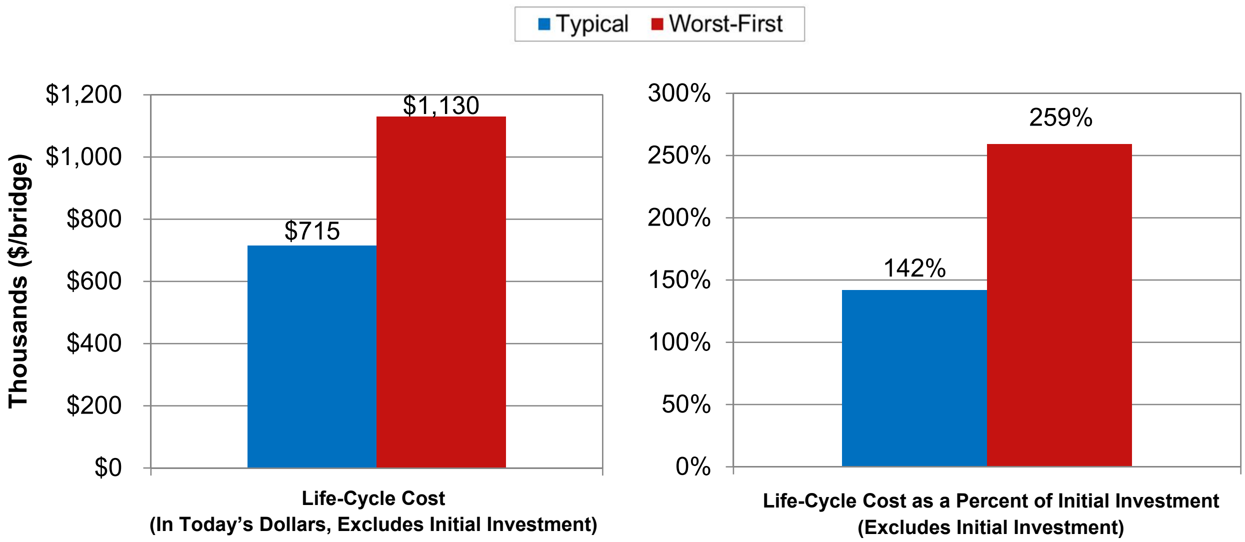
Figure 6-6: (a) Corrosion on a Bridge Structure Element (b) Large Culvert



Culverts [see **Figure 6-6 (b)**] tend to be more durable due to the fact that they are generally protected underground and are manufactured under more controlled conditions. They also deteriorate, but at a slower rate than bridges.

Bridges and large culverts in water are vulnerable to scour of their foundations, vessel collisions, and flood damage. Most bridges have expansion joints and bearings to prevent damage due to temperature changes and motion. These features can sometimes be damaged by the constant pounding of trucks passing over them, corrosion, excessive movement, or intrusion by rocks and other foreign materials. The results of the life-cycle cost analysis for bridge structures highlighting the magnitude of differences in costs for each strategy are shown in **Figure 6-7**.

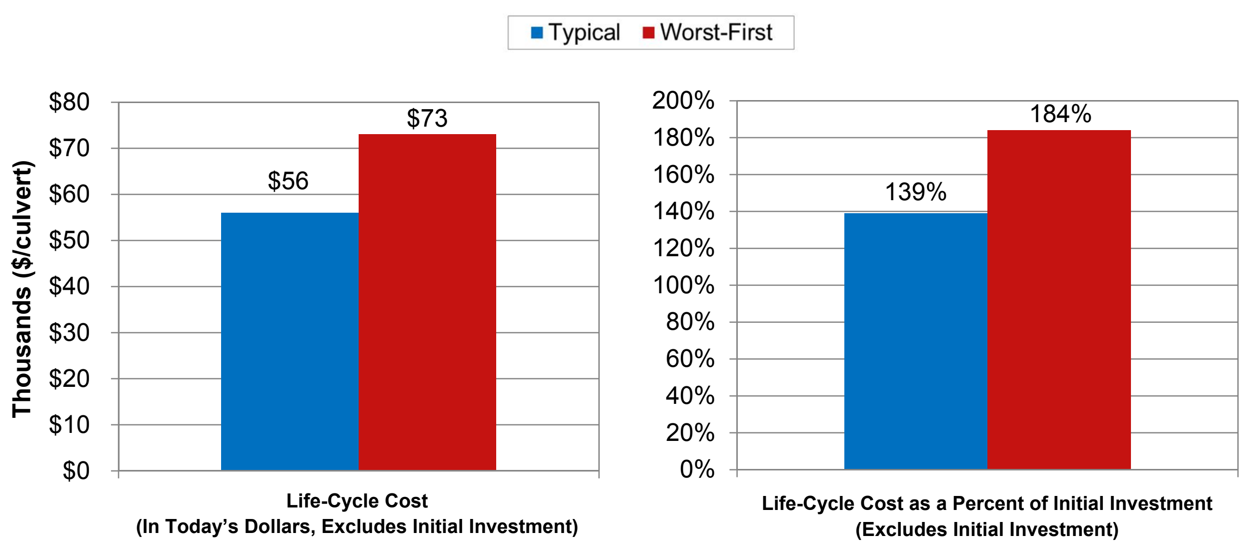
Figure 6-7: Summary of Life-Cycle Cost Analysis Results (Bridges)



MnDOT's typical preventative maintenance strategies extend the average service life of each structure from about 50 years to about 80 years. MnDOT's current policy saves about 37 percent of future life-cycle costs, a savings of $415,000 per bridge or $581 million for the entire NHS inventory over the 200 year analysis period. Small investments in improved asset management can have a very significant return when considering the large bridge inventory. The results illustrate that future costs (maintenance and capital) are approximately 1.42 (typical) to 2.59 (worst-first) times the initial cost of a capital project.

The results of the LCCA for large culverts highlighting the magnitude of differences in costs for each strategy are shown in **Figure 6-8**.

Figure 6-8: Summary of Life-Cycle Cost Analysis Results (Large Culverts)



MnDOT's typical strategy results in a savings of approximately 23 percent of future life-cycle costs, a savings of about $17,000 per large culvert, or $10 million over the inventory. The results further illustrate that future costs (maintenance and capital) are approximately 1.4 (typical) to 1.8 (worst-first) times the initial cost of a capital project.

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS

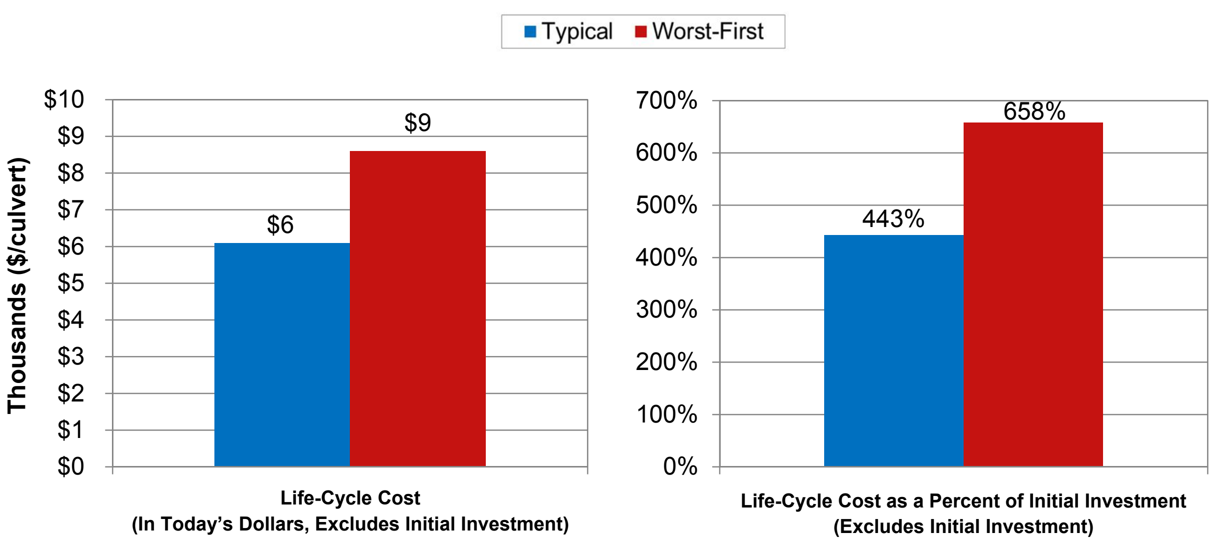
MnDOT maintains an inventory of more than 47,000 highway culverts on the state highway system, which includes NHS and non-NHS highways. These have a replacement value of approximately $1.7 billion. Culverts are inspected on an interval that is based on condition and risk: new assets are inspected every six years, while those in Poor condition may be inspected every year or every other year.

Culverts are flushed about once every 10 years to remove accumulated debris and a small fraction of them receive condition-based repairs as warranted. These assets are manufactured under relatively controlled conditions (compared to bridges) and, in most cases, have a very long life.

Drainage culverts do gradually deteriorate, exhibiting corrosion, settlement, deformation, scour from floods, impact damage, and buildup of debris. One relatively common problem is leakage where water intrudes into surrounding soil and washes it away, creating air pockets. The presence of these pockets tends to accelerate deterioration and can potentially cause a local collapse of the roadway above.

Figure 6-9 shows the results of the life-cycle cost analysis for highway culverts, highlighting the magnitude of differences in costs for each strategy.

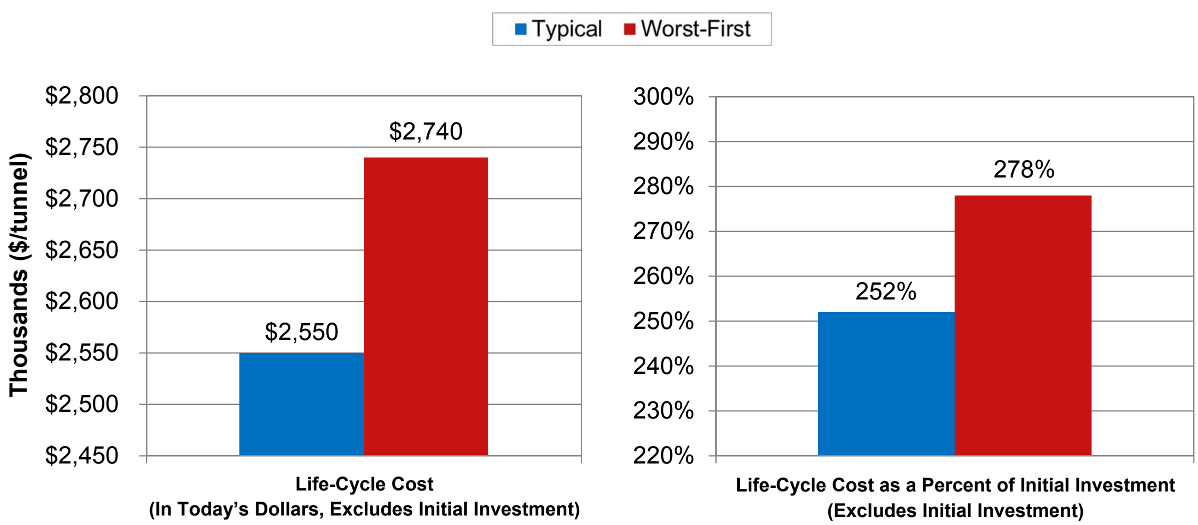
Figure 6-9: Summary of Life-Cycle Cost Analysis Results (Highway Culverts)



MnDOT performs maintenance activities on approximately two percent of the highway culverts per year, including resetting culvert ends, repairing joints, culvert lining, culvert replacement, and paving the lower interior of the culvert. MnDOT's current policy saves about 29 percent of future life-cycle costs, a savings of $2,500 per culvert, or $119 million for the whole inventory over the 200 year analysis period, compared to taking no maintenance action at all. Under these scenarios, the typical service life of both types of culverts is projected to be about 140 years. The future costs (maintenance and capital) for culverts are significant, ranging from 4.4 (typical) to 6.6 (worst-first) times the original cost of the culvert.

The results of the life-cycle cost analysis for deep stormwater tunnels highlighting the magnitude of differences in costs for each strategy are shown in **Figure 6-10**.

Figure 6-10: Summary of Life-Cycle Cost Analysis Results (Deep Stormwater Tunnels)



MnDOT maintains an inventory of 7 deep stormwater tunnels that are comprised of a total of 50 individual segments of varying lengths, covering a total length of approximately 70,000 linear feet. All seven tunnels have had detailed inspection studies completed, which identify specific conditions and repairs. The City of Minneapolis also performs a visual walk-through inspection of tunnels every two years. Tunnel conditions range from Good to Very Poor, with a majority of the segments in Poor or Very Poor condition. It should be noted that data for the LCCA are based on MnDOT's expert opinion and considered to be rough estimates. The best available estimate is that the total replacement value of these assets is approximately $240 million. A reliable maintenance schedule would have benefits similar in relative scale to culverts, but deep stormwater tunnels currently receive little maintenance. The future maintenance costs associated with deep stormwater tunnels range from 2.5 (typical) to 2.8 (worst-first) times the initial cost of the tunnel.

OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES

MnDOT maintains an inventory of almost 2,400 overhead sign structures and 476 high-mast light tower structures statewide. Current replacement values of all overhead sign structures and all high-mast light tower structures are approximately $200 million and $19 million, respectively. High-mast light tower structures are inspected on a five-year cycle due to MnDOT's formalized inspection program; a similar program does not currently exist for overhead sign structures. Instead, a less-formalized element-level inspection process and rating system is used for overhead sign structures. As a result of this TAMP process, MnDOT has developed a uniform statewide overhead sign structure inspection form and is working on creating a corresponding statewide inventory and inspection spreadsheet.

Figure 6-11 shows a typical overhead sign structure in the Twin Cities metro area. Unlike pavements and bridges, which are managed through a fairly mature process, protocols for inspection and management of overhead sign structures and high-mast light tower structures are relatively new. Over the last couple of years, MnDOT has invested significant resources to improve the way these assets are managed.

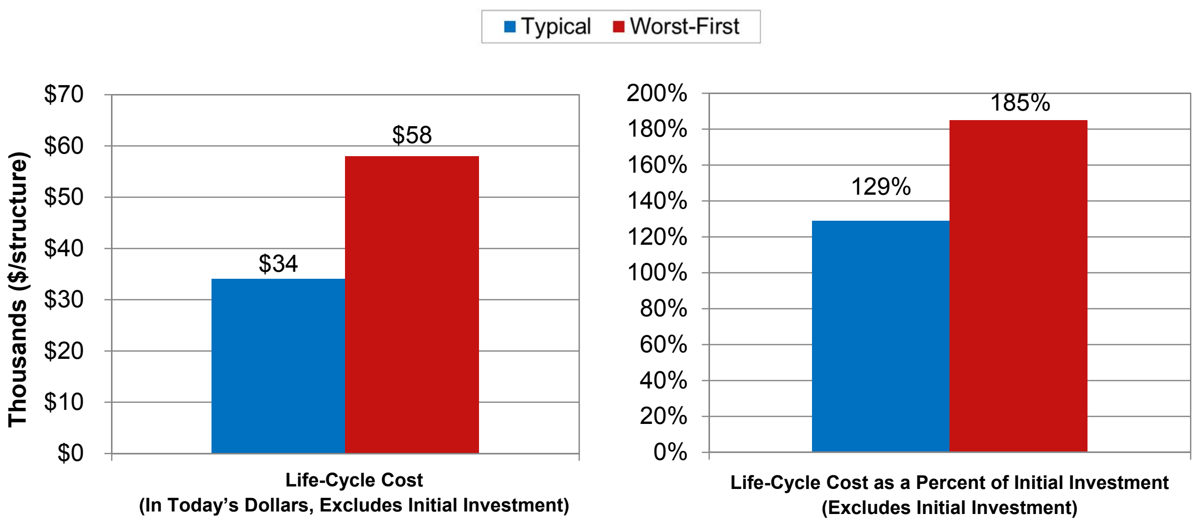
Figure 6-11: Overhead Sign Structure

Typical reactive maintenance activities performed on overhead sign structures include tightening nuts and removing grout. Minor rehabilitation activities performed include re-grading footing, replacing welds, removing catwalks/ lighting, and replacing individual elements. Typical maintenance actions perfomed on high-mast light tower structures include tightening and levelling of nuts, removing debris, and replacing components that are not functioning adequately.

Deterioration of these assets results from environmental loading (e.g. winds and other climatic effects like rain, snow, heat) and past improper installation of select components (e.g. nuts not tightened adequately during initial installation).

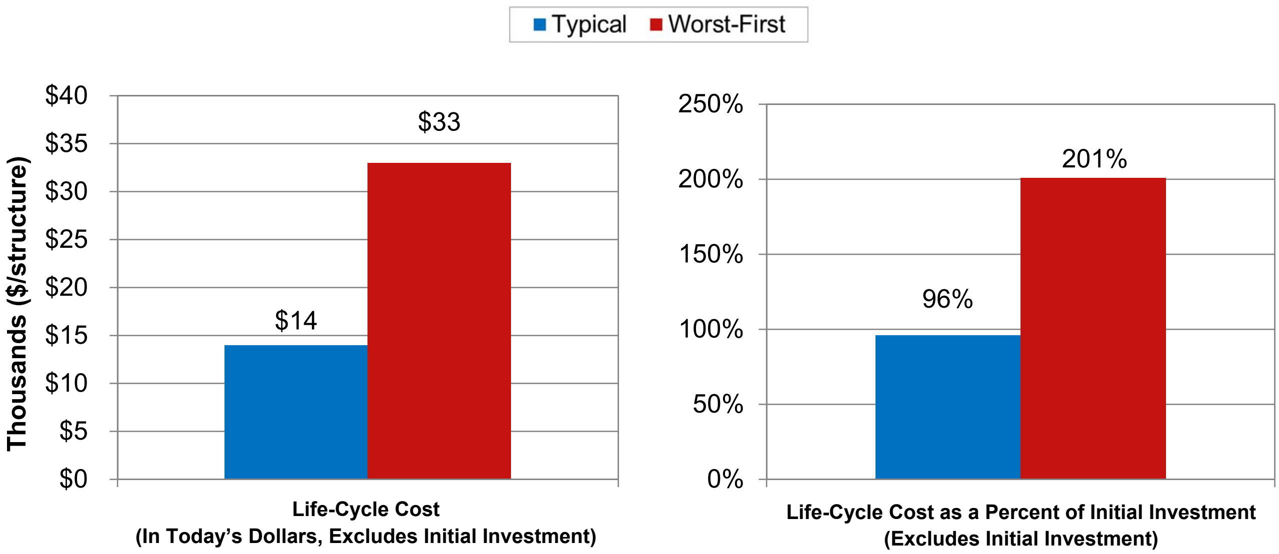
The results of the life-cycle cost analysis for overhead sign structures highlighting the magnitude of differences in costs for each strategy are shown in **Figure 6-12**. Future costs (maintenance and capital) associated with overhead sign structures range from 1.3 (typical) to 1.9 (worst-first) times the initial cost. The condition of the majority of the overhead sign structures is generally Fair to Good. Data for life-cycle cost analysis are based primarily on expert opinion and the best data available.

Figure 6-12: Summary of Life-Cycle Cost Analysis Results (Overhead Sign Structures)



The results of the life-cycle cost analysis for high-mast light tower structures highlighting the magnitude of differences in costs for each strategy are shown in **Figure 6-13**.

Figure 6-13: Summary of Life-Cycle Cost Analysis Results (High-Mast Light Tower Structures)



As with overhead sign structures, expert opinion was used to develop estimates for the maintenance costs associated with high-mast light tower structures. Future inspections and a consistent format for documenting the maintenance work performed on these structures and associated costs will help improve the life-cycle cost estimates. As demonstrated through the analysis, future costs (maintenance and capital) associated with high-mast light tower structures are estimated to range from 0.96 (typical) to 2.0 (worst-first) times the cost of the original structure.

Summary of Life-Cycle Cost Estimates

Figure 6-14 summarizes annualized life-cycle costs for each asset while **Figure 6-15** summarizes system-level, life-cycle cost analysis results by asset.

Figure 6-14: Annualized Life-Cycle Cost Estimates by Asset

ASSET CLASS	ANNUALIZED COST
Pavements	$12,000 per lane-mile
Bridges: Large Bridges	$16,000 per bridge
Bridges: Culverts 10 feet or greater	$1,300 per large culvert
Hydraulic Infrastructure: Highway Culverts	$150 per small culvert
Hydraulic Infrastructure: Deep Stormwater Tunnels	$30,000 per mile of tunnel
Other Traffic Structures: Overhead Sign Structures	$900 per structure
Other Traffic Structures: High-Mast Light Tower Structures	$400 per structure

The information in **Figure 6-14** shows how much it costs per year to maintain an asset when construction, inspection, maintenance, and disposal costs are totalled and divided by the LCCA period (number of years).

Figure 6-15: System-Level Life-Cycle Cost Estimates

ASSET CLASS	REPLACEMENT COST	FUTURE COST: WORST-FIRST	FUTURE COST: CURRENT POLICY
Pavements (NHS)	16,000	15,700	6,600
Pavements (non-NHS)	13,600	13,400	5,600
Bridges	4,000	1,600	1,000
Highway Culverts	1,700	400	285
Deep Stormwater Tunnels	240	140	130
Overhead Sign Structures	200	140	80
High-Mast Light Tower Structures	20	20	10

Note: All amounts are million dollars, in today's dollars

The information in **Figure 6-15** shows that timely preservation work is very effective in reducing life-cycle costs for pavements and bridges, primarily by extending the lifespans of these assets. Currently, MnDOT does not have fully-implemented tools to optimize preservation policies. As a result, it is believed that greater cost savings could be achieved through fine-tuning the timing and application of preservation actions. For assets like overhead sign structures and high-mast light tower structures, routine inspection of the structures to ensure that they are operating as intended is expected to reduce life-cycle costs.

Improving Life-Cycle Management

The primary purpose of life-cycle cost analysis is to answer the question: Which investments, made today, are most cost-effective in the long-term to keep the infrastructure in service? Often, the answer to this question is preventive maintenance or preservation work on assets that are in relatively good condition. Life-cycle cost analysis is used to identify and prioritize the best opportunities and timing for this strategic activity. In transportation asset management, state-of-the art life-cycle management is quantitative and scientific, based on research and analysis of historical condition and performance data. Predictive models for deterioration, cost, action effectiveness, and risk allow an agency to reliably forecast the outcomes of policies and program development decisions. Combined with the ability to generate policy and program alternatives, this approach enables better-informed decision-making.

MnDOT has tools in place for pavements and bridges to help optimize life-cycle management. However, these tools are not fully implemented because either the necessary research for predictive models has not been performed or maintenance costs could not easily be merged with performance data to document the increased costs of maintenance if capital improvements are not performed. However, the agency does have sufficient data to support such research for several of the major asset classes.

During the development of this TAMP, MnDOT developed a set of spreadsheet models to approximate a life-cycle cost analysis. Such models could be extended to make use of research results for any asset class, provided that a complete inventory and routine inspection process is in place. Examples of LCCA spreadsheet models are included in the life-cycle cost section of the **Technical Guide**.

Key conclusions from the LCCA that serve as drivers for improving existing management practices and investment strategies are summarized below:

- Investments in pavement preservation have significantly reduced life-cycle maintenance costs. MnDOT should continue to proactively maintain its pavements and should closely manage preventive maintenance activities for the entire state highway system.

- Strive to lower network life-cycle costs by considering major rehabilitation or reconstruction activities for pavements that are over 50 years old (in lieu of treatments like mill and overlays that become less effective as the pavement structure ages). When funding allows, MnDOT should invest in long-term fixes at the end of a pavement's life. Quantifying the benefits of performing the right fix for roads over 50 years old will allow MnDOT to have considerable life-cycle cost savings. For example, MnDOT's Materials Office works closely with the districts to recommend the most appropriate pavement life-cycle cost fixes at the project level – based on targets, financial commitments, investment strategies, age, and history.

- Invest in research studies to better understand deterioration of bridges, culverts, deep stormwater tunnels, overhead sign structures and high-mast light tower structures, thereby improving the accuracy of long-term investment decisions. For example, the effectiveness of slipliners to extend culvert life is understood only anecdotally, as is the phenomenon of void formation around the culvert joints. Such understanding would help MnDOT select more appropriate maintenance actions and develop new and more effective treatments.

- Make a conscious effort to move from a reactive to a more proactive approach for culverts, deep stormwater tunnels, overhead sign structures and high-mast light tower structures. Overhead sign structures and high-mast light tower structures must be inspected more consistently in order to anticipate problems that other agencies have found to be common, especially fatigue cracking.

- The LCCA demonstrated the ongoing maintenance and capital commitments associated with adding assets to the state's inventory. These costs represent significant future liabilities that are not always accounted for in traditional planning and programming processes. Therefore, MnDOT should develop a process for considering them when contemplating capital improvements.

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Chapter 7

PERFORMANCE GAPS

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PERFORMANCE GAPS

Overview

Asset condition is a critically important component of the highway system's overall performance. Assets that are maintained in a state of good repair support safe and efficient travel and are less costly to operate over an entire life-cycle. MnDOT continuously monitors and reports asset condition using the business practices and performance measures described in **Chapter 3**. This information serves as the basis for MnDOT's preservation driven investment programs and maintenance activities. For pavements and bridges, asset condition is also used to identify performance gaps, defined here as the difference between existing and desired performance.

This chapter presents 2012 condition results alongside target recommendations for state highway pavements, bridges, highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures. These target recommendations provide points of reference for evaluating condition and the adequacy of MnDOT's planned investment. New targets for highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures also have the potential to elevate the importance of these asset categories and provide a basis for developing and evaluating investment strategy alternatives.

STATUS OF TARGETS APPEARING IN THE TAMP

TAMP target recommendations reflect the expert judgment of MnDOT staff and were identified having considered a combination of current policy and investment direction (e.g. MnSHIP), federal and state requirements (e.g. MAP-21, GASB 34), risk, expected or anticipated deterioration, principles of life-cycle costs, and public expectation (as solicited through past planning efforts).

Chapter 2 further described the MnSHIP development process looking at tradeoffs between investment levels, performance levels, and risks to evaluate and select investment priorities. **Chapter 3** described the process outcomes and how they were used to help identify targets and outcomes for pavement and bridge condition.

For non-pavement and non-bridge assets, Work Groups developed asset-specific target methodologies, having considered existing and anticipated future conditions, current information on capital and maintenance investments, anticipated deterioration, and risk. For example, the Hydraulic Work Group identified the number of culverts in Poor and Very Poor condition, determined how many of them deteriorate to a worse condition annually, made judgments on the length of time that a culvert should remain in Poor or Very Poor condition given risk, and determined how many culverts could feasibly be repaired annually. The Technical Guide includes several tables that illustrate how these data were used to calculate targets. A similar methodological approach was followed for recommending targets for overhead sign structures.

Specific targets may be approved, modified or rejected through MnDOT's public planning process and senior leadership review. Approved or modified targets for the asset categories covered below will be used to calculate investment need and guide resource allocation decisions in the next iteration of MnSHIP. These targets will also be used to further develop and refine MnDOT's asset management strategies.

Target Recommendations

As discussed previously, the TAMP uses the terms target and plan outcomes to differentiate between desired outcomes and the outcomes MnDOT plans to achieve within the constraints of available resources. A single number can represent both ideas if MnDOT plans to achieve its desired outcome. In situations where a target and a plan outcome diverge due to insufficient resources, MnDOT uses the target to communicate need, while managing its program and maintenance activities to the plan outcome. This terminology eliminates the need for aspirational and constrained targets, as described in MnSHIP. For further detail on these terms, please see **Chapter 3**.

RECOMMENDED PAVEMENT TARGETS

Figure 7-1 presents MnDOT's existing pavement condition targets, plan outcomes (as reported in MnSHIP), and the new targets recommended in this TAMP.

This TAMP recommends that MnDOT recognize its plan outcomes on the Interstate and non-Interstate NHS as targets for the purpose of defining its desired outcomes and calculating investment needs. While slightly less aggressive than the target used to calculate need in MnSHIP, maintaining Poor pavement condition on no more than two percent of the Interstate System and four percent of the non-Interstate NHS represents a performance standard that is consistent with traveler expectations and MnDOT's strategic goals and objectives.

Off the NHS, this TAMP recommends MnDOT adopt a pavement condition target of no more than ten percent Poor. This target, which is a slightly higher than existing conditions, is less aggressive than the no more than three percent Poor target MnDOT has historically used to calculate needed investment in non-NHS pavement. Adopting a less aggressive pavement condition target on the non-NHS reflects emerging federal and state policy directing MnDOT to focus its resources on priority networks (e.g. NHS). Outreach conducted as part of MnSHIP also found that a majority of MnDOT's external stakeholders are willing to trade pavement condition on low volume roads for continued investment in other performance areas, such as safety, mobility and non-motorized transportation.

Unlike this TAMP's target recommendations for Interstate and non-Interstate NHS pavement condition, a no more than 10 percent Poor target on the non-NHS is not likely to be met under existing revenue projections. MnDOT expects the share of non-NHS roadway miles with Poor pavement condition to increase from 7.5 percent in 2012 to 12 percent in 2023 – a difference of 303 miles. While consistent with MnSHIP investment priorities, this outcome poses significant user costs, risks damage to MnDOT's reputation, and limits the agency's opportunities to manage assets in a cost-effective manner. Adopting this target on the non-NHS supports strategic prioritization while still conveying the idea that there is a gap between MnDOT's desired and planned outcome in this performance area.

This TAMP recommends retiring MnDOT's pavement condition target of 5-9 percent across all state highways. A single statewide pavement condition result is a useful summary reporting tool, but the 5-9 percent target is made redundant by MnDOT's measures of pavement condition on Interstates, the non-Interstate NHS and the non-NHS. These sub-system measures provide a better, more accurate indication of performance because they track more closely with how MnDOT manages and invests in its assets.

Figure 7-1: Existing and Recommended Pavement Condition Targets

		MNSHIP		TAMP	
System	**2012 Condition (% Poor)**	Aspirational Target (% Poor)	Constrained Target/10-year Anticipated Outcome (% Poor)	Target Recommendation (% Poor)	Plan Outcome (% Poor)
Interstate	2.4 %	≤ 2%	2 %	≤ 2 %	2 %
Non-Interstate NHS	4.3 %	≤ 4%	4 %	≤ 4 %	4 %
Non-NHS	7.5 %	NA	12 %	≤ 10 %	12 %

RECOMMENDED BRIDGE TARGETS

As identified in **Figure 7-2**, the TAMP recommends no changes to MnDOT's bridge condition targets. Consistent with MnSHIP investment priorities, MnDOT expects to meet condition targets for both NHS and non-NHS bridges. Compared to current condition, MnDOT expects the share of NHS deck area on Poor condition bridges to drop slightly from 4.7 percent in 2012 to 2 percent in 2023. The share of non-NHS deck area on Poor condition bridges is expected to increase from 2.1 percent to 6 percent, but this remains below MnDOT's target of 8 percent.

Figure 7-2: Existing and Recommended Bridge Condition Targets

		MNSHIP		TAMP	
System	**2012 Condition (% Poor)**	Aspirational Target (% Poor)	Constrained Target/10-year Anticipated Outcome (% Poor)	Target Recommendation (% Poor)	Plan Outcome (% Poor)
NHS	4.7 %	≤ 2%	2 %	≤ 2 %	2 %
Non-NHS	2.1 %	≤ 8 %	6 %	≤ 8 %	6 %

RECOMMENDED HIGHWAY CULVERT AND DEEP STORMWATER TUNNEL TARGETS

Figure 7-3 presents the current condition of MnDOT's highway culverts and deep stormwater tunnels. Performance targets for the condition of these assets were not available during the development of MnSHIP. This TAMP, reflecting the expert judgment of the Hydraulics Work Group, recommends that MnDOT establish targets that no more than eight percent of highway culverts be in Poor condition and no more than three percent be in Very Poor condition. These targets represent a slight improvement over 2012 condition levels. For deep stormwater tunnels, this TAMP recommends that MnDOT establish targets in line with those for highway culverts. This target represents a substantial improvement over current condition; however, a plan is in place to systematically address deep stormwater tunnel needs over the next several years, including within a very large tunnel under I-35W in Minneapolis. Deep stormwater tunnel condition will improve to 23 percent Poor and 11 percent Very Poor as a result of rehabilitating the I-35W (south) tunnel.

Figure 7-3: Existing Conditions and Recommended Highway Culvert and Deep Stormwater Tunnel Condition Targets

		MNSHIP	TAMP	
Asset	2012 Condition	Aspirational and Constrained Target / 10-year Anticipated Outcome	Target Recommendation	Plan Outcome
Highway Culverts	10 % Poor; 6 % Very Poor	NA	≤ 8 % Poor; ≤ 3 % Very Poor	TBD
Deep Stormwater Tunnels	39 % Poor; 14 % Very Poor	NA	≤ 8 % Poor; ≤ 3 % Very Poor	TBD

Note: Investment need identified to meet target; commitment will be determined in MnSHIP

RECOMMENDED OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES TARGETS

Figure 7-4 presents the current condition of MnDOT's overhead sign structures and high-mast light tower structures. Performance targets for the condition of these assets were not available during the development of MnSHIP. This TAMP, reflecting the expert judgment of the other traffic structures Work Group, recommends that MnDOT establish a target of no more than four percent of its overhead sign structures in Poor condition and no more than two percent be in Very Poor condition. MnDOT expects the share of overhead sign structures in Poor condition to decline in the future as installation specifications and protocols are put in place.

At the time of the development of this TAMP, MnDOT was in the process of redefining condition rating criteria for high-mast light tower structures and there was insufficient data to appropriately recommend a condition target. A target for this asset category will be revisited during the next update of MnSHIP.

Figure 7-4: Recommended Existing Conditions and Recommended Overhead Sign Structures and High-Mast Light Tower Structures Condition Targets

		MNSHIP	TAMP	
Asset	2012 Condition	Aspirational and Constrained Target / 10-year Anticipated Outcome	Target Recommendation	Plan Outcome
Overhead Sign Structures	6 % Poor; 8 % Very Poor	NA	≤ 4 % Poor; ≤ 2 % Very Poor	TBD
High-Mast Light Tower Structures	6 % Poor; 15 % Very Poor	NA	TBD	TBD

Note: Investment need identified to meet target; commitment will be determined in MnSHIP

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Chapter 8

FINANCIAL PLAN AND INVESTMENT STRATEGIES

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FINANCIAL PLAN AND INVESTMENT STRATEGIES

Overview

When developing investment priorities, MnDOT accounts for various factors that include revenue trends, federal and state law, level-of-service provided by the system, and public input. Over the next 10 years, MnDOT's priorities will aim to balance investments in preservation of the existing infrastructure system with investments in safety, multi-modal transportation, and other projects that improve the economic competitiveness of Minnesota and the overall quality of life for Minnesotans.

Financial trends indicate that revenues have slowed compared to previous decades. As a result, it is imperative that MnDOT look for investment opportunities that provide the best "bang for the buck" in the long term, with the objective of minimizing life-cycle costs. Timely investments in both capital and preventive maintenance treatments help extend the service life of assets while reducing life-cycle costs (discussed in **Chapter 6**). Optimal life-cycle investment strategies are actively pursued when identifying investment priorities. Tradeoffs between investment areas, performance levels, public expectations, and risks play a significant role in MnDOT's ability to achieve lowest life-cycle costs.

This chapter summarizes funding sources, trends, and current revenues, and highlights investment levels and strategies for the asset categories included in this TAMP. It also includes estimates of the investment levels necessary to achieve asset condition performance targets by the end of the TAMP's time horizon (2023).

Revenue Sources

Transportation improvements on Minnesota's state highways are funded by taxes and fees from four main revenue sources:

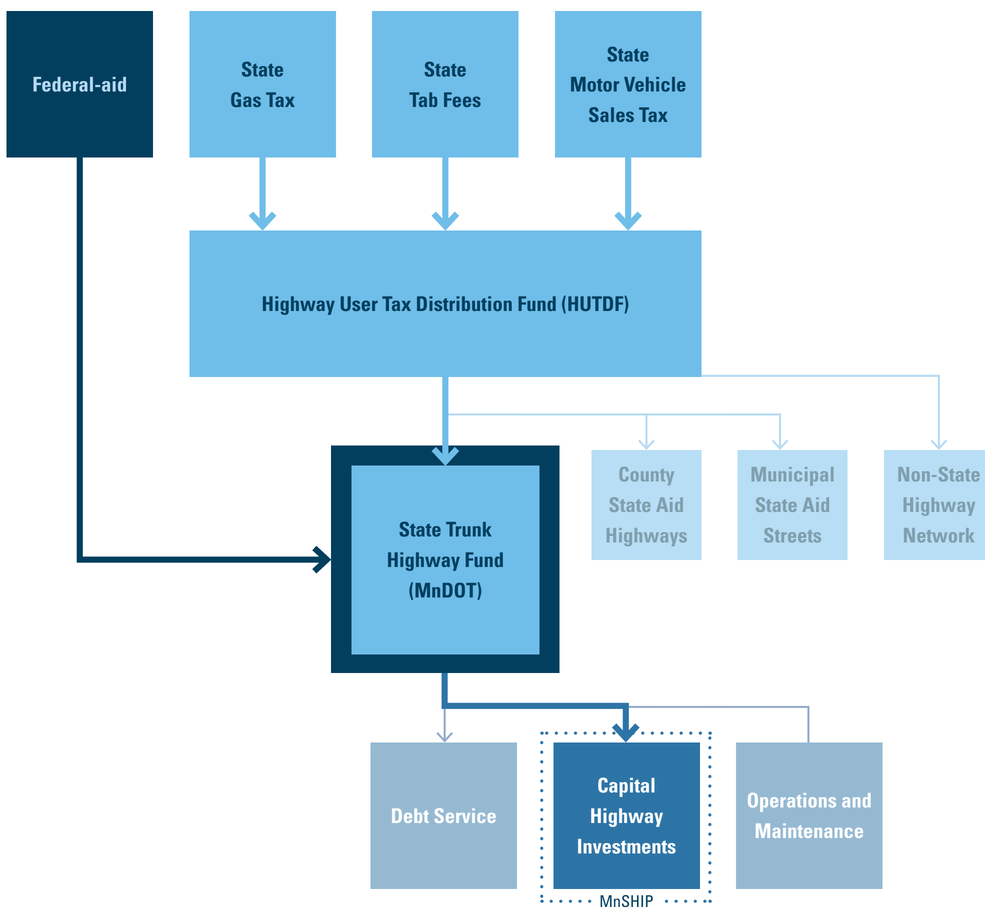
- Federal-aid (gas tax and General Funds)
- State gas tax (motor fuel excise tax)
- State tab fees (motor vehicle registration tax)
- State motor vehicle sales tax

The revenues from Federal-aid go directly to the State Trunk Highway Fund (see **Figure 8-1**), which funds capital improvements on the state highway system. Revenues from the main state sources, as well as various smaller revenues, are pooled into the Highway User Tax Distribution Fund (HUTDF) and divided between state highways, county roads, and city streets based on a constitutional formula.

Approximately five percent of these funds are set aside for the Non-State Highway Network (which includes the Flexible Highway Account, Township Roads Account, and Township Bridges Account). The remaining 95 percent is split among the State Trunk Highway Fund, County State Aid Highways, and Municipal State Aid Streets. The portion allocated from the HUTDF to the State Trunk Highway Fund (62 percent) must first go toward any existing debt repayment and is then divided among operations and maintenance activities and capital improvements on state highways.

In addition to the four main sources of funding, Minnesota also sells transportation bonds to support highway improvements. However, unlike the other revenue sources, bonds must be repaid with interest. The primary purpose of transportation bonds is to enable MnDOT to accelerate the delivery of projects and avoid construction cost increases due to inflation.

Figure 8-1: Revenue Sources and Uses for the Minnesota State Highway Network

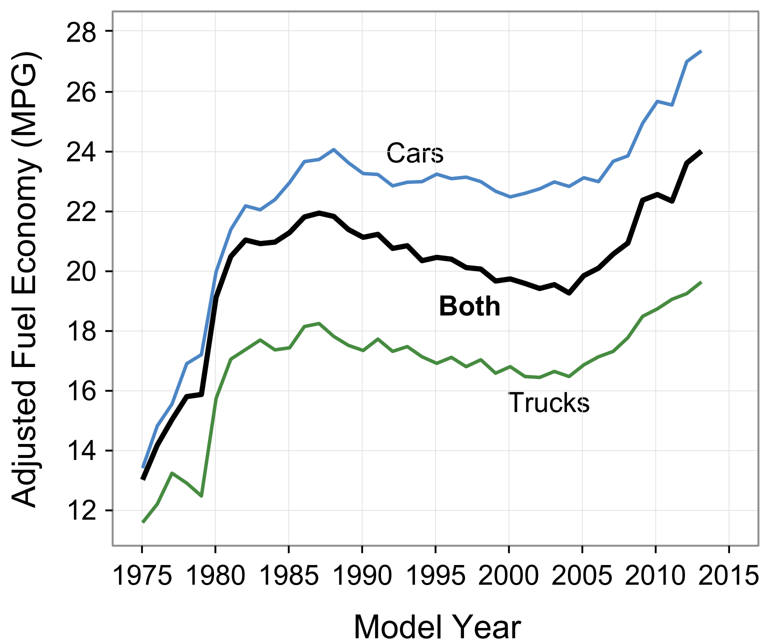


REVENUE TRENDS

Revenue growth has slowed relative to previous decades. There are several explanations as to why MnDOT expects revenues to grow more slowly between 2014 and 2033 as compared to previous years. These include:

- Vehicle fuel efficiency is improving (see **Figure 8-2**). Minnesotans, as well as Americans in general, are driving more fuel-efficient vehicles and consuming less gasoline. Increased fuel efficiency has been required by the federal government through the Corporate Average Fuel Economy (CAFE) program. While lowered emissions have a positive impact on the environment, the increased efficiency results in less funding because the gas tax is one of the major sources of both federal and state revenue.

Figure 8-2: Average Fuel Economy (Miles Per Gallon) by Model Year, 1975-2013[1]

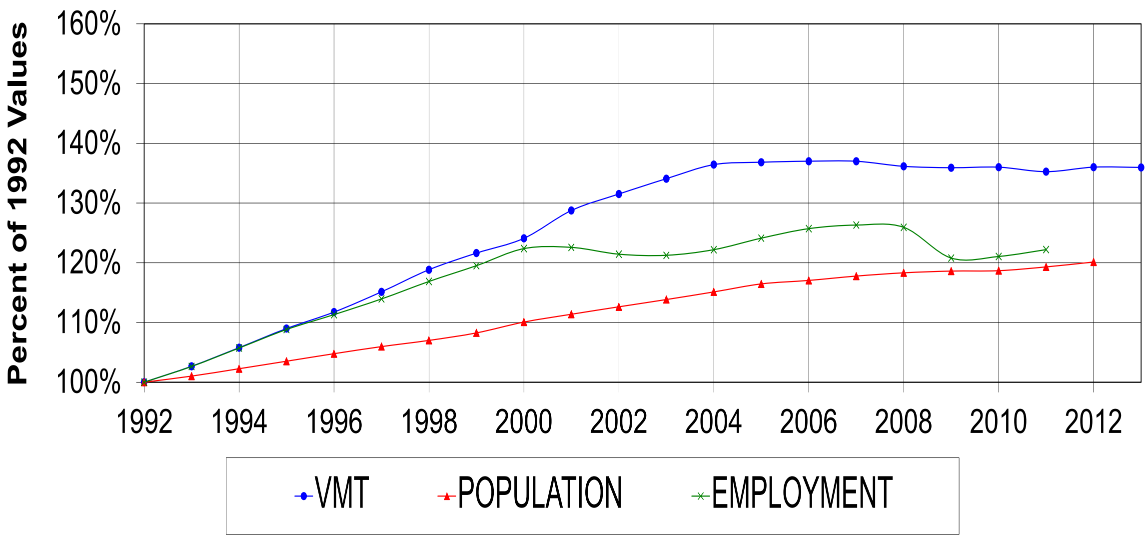


- Due to advances in engine and battery technologies, more conversions are occurring from gasoline to non-taxable energy sources. These conversions ultimately result in a loss of transportation revenue; electric and hybrid vehicles consume less or no fuel and thus contribute less revenue to the State Trunk Highway Fund.

1 US Environmental Protection Agency (EPA): http://epa.gov/fueleconomy/fetrends/1975-2013/420s13002.pdf

- People are driving less (see **Figure 8-3**). While there was significant growth in the number of miles traveled on the highway system in the 1990s and early 2000s, this growth leveled off in 2004 and vehicle miles traveled (VMT) has slightly declined over the last seven to eight years. Total VMT is still expected to increase along with economic and population growth, but per capita VMT is projected to remain relatively flat over the next 20 years due to demographic, technological, and behavioral changes. As a result, it is not likely that state motor fuel excise taxes will grow appreciably. Federal-aid revenues, based on motor fuel excise taxes and transfers from the US General Fund, are also expected to grow slowly over the next 20 years; increases in recent years are far less than in decades past.

Figure 8-3: Trends in Vehicle-Miles Traveled, Population, and Employment in Minnesota



- New vehicle sales have slowed. Consumers are keeping their cars longer, decreasing the amount of revenue generated by the number and price of vehicles sold. This also means lower vehicle registration tax (tab fee) revenues, as these taxes are based on the underlying value of registered vehicles. As the fleet of registered vehicles ages, the state is able to generate less revenue from these sources. MnDOT expects modest annual growth in motor vehicle sales tax and tab fee revenues.

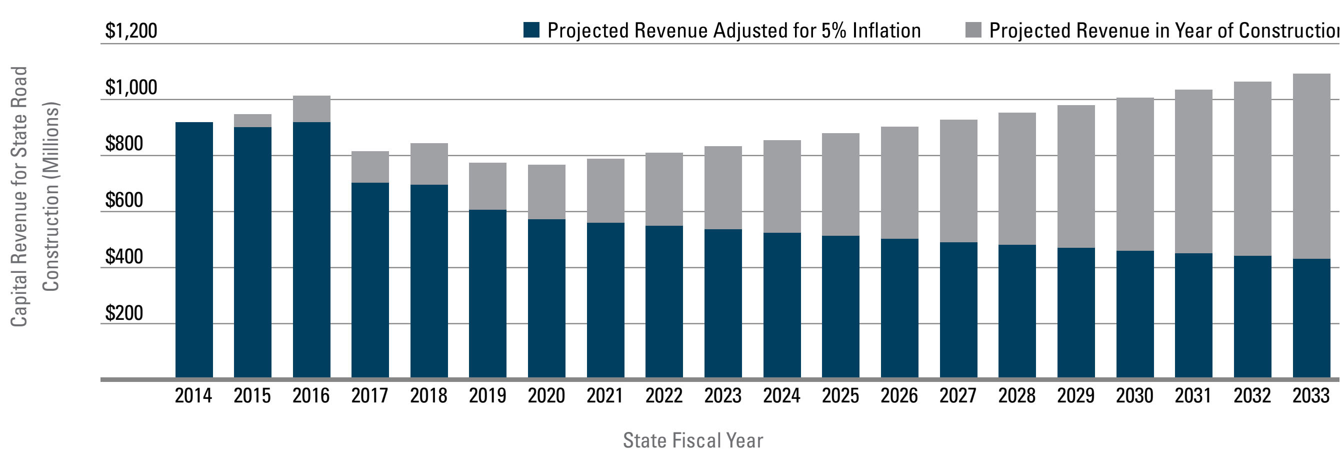
Revenue and Inflation

CAPITAL

Over the next 10 years, MnDOT estimates that $8 billion in revenue will be available for capital investment on the state highway system – approximately $800 million per year. This estimate is based on the assumption that no new major sources of revenue will be introduced and that the majority of MnDOT's future revenues will originate from the four main revenue sources shown at the top of **Figure 8-1**. Furthermore, the estimate assumes that temporary funding sources available over the past five years will have been drawn down or expired completely by the end of the decade. For example, the four-year, $357 million Better Roads for a Better Minnesota program will have mostly concluded by 2015, and the Chapter 152 bond authorization will expire in 2018.

MnDOT does anticipate that the actual amount of funding it receives from the State Trunk Highway Fund will increase on an annual basis over the next 10 years by approximately two percent per year. Unfortunately, however, construction costs are growing more quickly than revenues. Expected revenues will lose buying power over time as construction costs (e.g. fuel, raw materials, equipment, labor) continue to grow at an annual rate of approximately five percent, exceeding the annual revenue growth rate of approximately two percent. This imbalance is expected to persist as a long-term planning challenge for the state. **Figure 8-4** illustrates the impact of five percent inflation on annual buying power (blue) versus nominal revenues (grey) in future years of construction. The net effect is that inflation will erode the buying power of revenues by nearly 60 percent by 2033, given the assumptions stated above.

Figure 8-4: Anticipated Construction Revenue by Year Including Adjustments for Inflation



Operations and Maintenance

MnDOT's current operations and maintenance (HSOP) four-year budget (2012-2015) is approximately $860 million, with an operations and maintenance need of approximately $1.25 billion over this same timeframe. The result is an existing four-year budget gap without inflation of approximately $390 million and $410 million with inflation. Specific to TAMP assets, the current operations and maintenance budget includes $43.9 million for drainage, $19 million for lighting, $107.7 million for smooth roads and shoulders, and $36.5 million for bridge preventive and reactive maintenance, which does not include $21.2 million for bridge inspection and inventory (see **Figure 8-5**). In addition

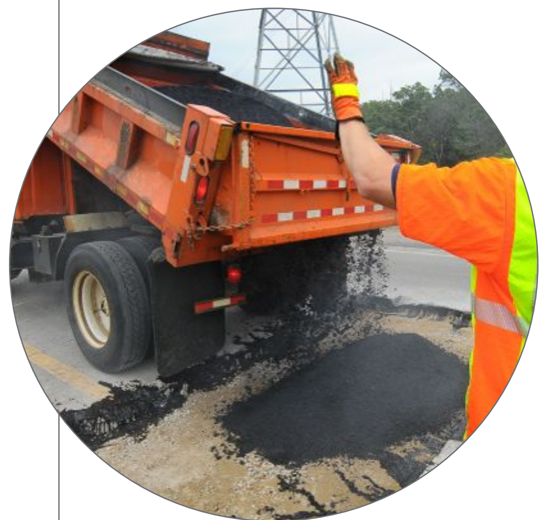
Figure 8-5: HSOP Budget Summary and Funding Gap, Specific to TAMP Assets: 2012-20151 (Dollar amounts shown in millions)

INVESTMENT AREA	CURRENT BUDGET	NEED BEYOND CURRENT BUDGET	CURRENT GAP	GAP INCLUDING INFLATION
Drainage	$43.9	$68.0	$24.1	$25.3
Safety and Guidance: Lighting	$19.0	$39.8	$20.8	$21.8
Smooth Roads: Roads	$77.8	$86.0	$8.2	$8.8
Smooth Roads: Shoulders	$29.9	$40.0	$10.1	$10.6
Structures: Bridge Preventative	$16.1	$27.4	$13.0	$13.6
Structures: Bridge Reactive	$20.4	$33.6	$8.6	$9.0
Structures: Other Infrastructure -Inspection/Inventory	$21.2	$26.0	$4.8	$94.1
TOTAL	**$228.3**	**$320.8**	**$89.6**	**$94.1**

Notes: Budget dollars shown in millions over the next two (2) bienniums (2012-2015); Current budget listed as zero (0); item is listed for the purpose of accounting for inflation

to the HSOP budget, MnDOT's capital program also includes two setasides to complement operations and maintenance activities. The average annual preventative maintenance setaside is approximately $20 million statewide. Each of MnDOT's eight districts also programs an annual Bridge and Road Construction (BARC) setaside, which is typically $2-5 million per district.

As part of the HSOP development process, a more formal Enterprise Risk Management (ERM) approach was used to help determine funding gaps – where additional funding could be directed if money became available. **Chapter 5: Risk Management Analysis** and the **TAMP Technical Guide** provide additional information on ERM. Operations and maintenance funding gaps by investment areas were determined by identifying and ranking investments based on existing budget levels, anticipated risk levels, and current organizational strengths. While this process helped to establish some acceptable risks, it did not compare and prioritize work activities ("tradeoffs") or include life-cycle cost considerations (identified in **Chapter 6**).



Funding Allocation

State and federal laws impose few restrictions on the allocation of funding between system expansion and preservation, or on preservation between various asset categories. At the federal level, the new surface transportation bill, Moving Ahead for Progress in the 21st Century (MAP-21), established new requirements for federal highway programs. MAP-21 expanded the number of highways in the National Highway System (NHS) to include Interstates, most US Highways, and other principal arterials, totaling about 45 percent of Minnesota's state highway system. The bill establishes national goals and requires USDOT to establish performance measures for the NHS in several categories.

For many years, MnDOT has allocated most revenue to its eight districts to make progress toward performance targets and key objectives and to address district-specific risks. With the passage of MAP-21, federal policy and performance requirements direct the majority of federal funds to the NHS. Continuing to allocate all revenue to the districts may not meet statewide NHS targets in an optimal way. In addition, MnDOT must manage the risk that deteriorating state highway assets could negatively affect Minnesota's bond rating. MnDOT developed the Statewide Performance Program (SPP) and District Risk Management Program (DRMP) to respond to these changes.

- The SPP focuses on federal performance requirements identified in MAP-21, which require MnDOT to make progress toward pavement, bridge, safety, and congestion performance targets. Failure to do so results in the loss of some federal funding flexibility. MnDOT's functional and district offices work collaboratively to select SPP projects, which primarily include rehabilitation and replacement fixes for existing pavement, bridges, and roadside infrastructure on NHS roads. The SPP also funds select projects that improve safety and mobility.

- The DRMP focuses on non-NHS highways and addresses unique conditions at the district level. It allocates funding to MnDOT districts, which identify and prioritize projects under this program. However, project selections are evaluated statewide through a collaborative process to ensure that each district is addressing district-level risks while making progress toward statewide goals. DRMP projects focus on pavement, bridge, and roadside infrastructure on low-volume roads, and the DRMP funds the majority of safety and mobility improvements.

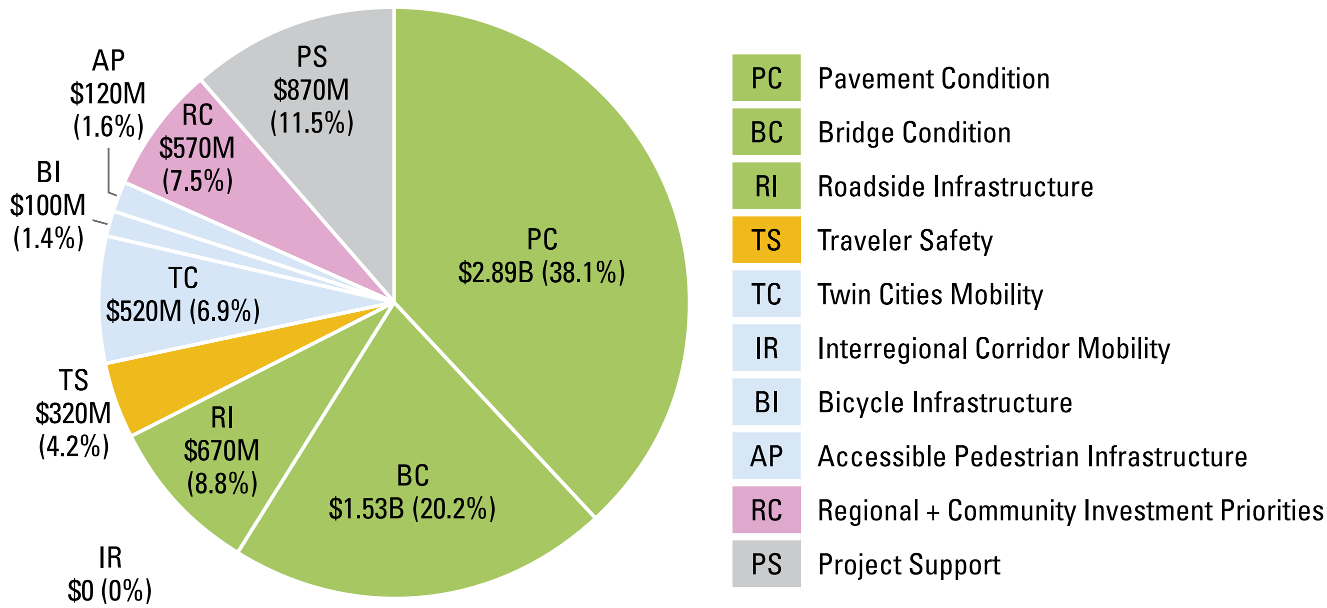
Investment Priorities and Direction

As shown on **Figure 8-6**, MnDOT's primary emphasis for the next 10 years is preservation in all asset management categories – Pavement Condition, Bridge Condition, and Roadside Infrastructure Condition. This will allow MnDOT to achieve multiple objectives through coordinated investments. For example, improving drainage infrastructure, which is part of Roadside Infrastructure Condition, helps pavements last longer. Funding Bridge Condition at a high level of performance supports traveler safety. Investing in Pavement Condition can enhance the bicycle network through shoulder repairs. The MnSHIP development process – including stakeholder involvement, scenario planning, and financial direction – is explained in greater detail in **Chapter 2: Asset Management Planning and Programming Framework** and the **TAMP Technical Guide**.

The Roadside Infrastructure category includes highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures, as well as a number of other asset categories not included in this TAMP. For pavements and bridges, MnDOT anticipates that this investment level is enough to keep conditions stable on the NHS, but not on non-NHS routes.

In 2014-2023, MnDOT is taking an investment direction similar to the approach taken in recent years, which addresses high-priority improvements in all investment categories.

Figure 8-6: 2014-2023 Capital Investments



Asset Investment Strategies

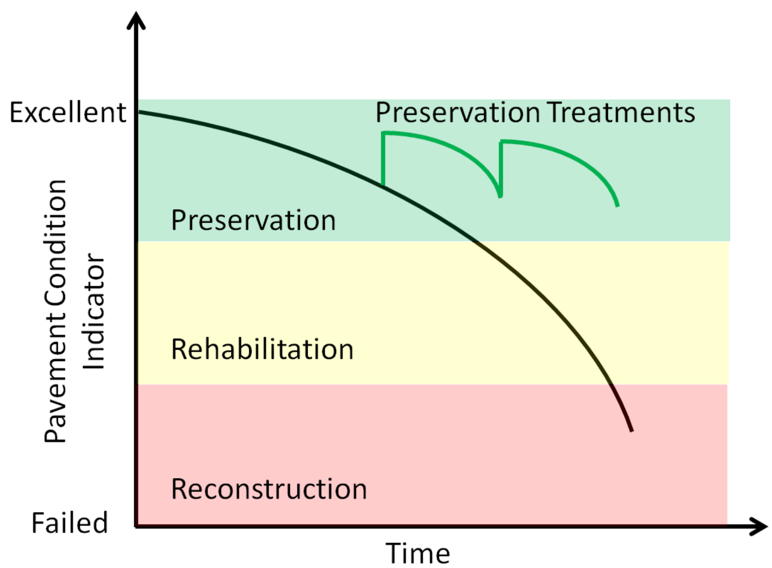
Pavement and bridge conditions in Minnesota are relatively well-understood and -documented according to longstanding condition surveys and databases. Programmed preventive maintenance capital investments are included in model assumptions. Information from the pavement management system is used by the districts to determine the appropriate type and level of repair for each pavement section. Since 2010, MnDOT has been developing, refining, and implementing its Bridge Replacement and Improvement Management (BRIM) system to quantify various risk factors that are appropriate for setting priorities among bridge projects. Each district uses BRIM to help prioritize work. Recently completed inventories and condition surveys are also included in **Chapter 4** of this plan.

Even with these data sources in place, MnDOT cannot fully realize life-cycle costs for its assets. Capital investment decisions identified in **Figure 8-6** do not consider non-capital funded maintenance activities. The life-cycle analysis results in Chapter 6 give MnDOT a great starting point moving forward, but additional work is needed to collect better data on maintenance investments and results. The inability to forecast future conditions that consider all maintenance activities, capital and non-capital, can lead to a less-than-optimal life-cycle investment approach, as illustrated in **Chapter 6**. As a result, MnDOT has an effort underway to better track maintenance investments associated with TAMP assets, which will in turn help the agency work toward achieving optimal life-cycle costs. Other asset-management-enhancing commitments and recommendations identified during the TAMP development process are included in **Chapter 9: Implementation and Future Developments**. When planning for future state highway capital investment needs, MnDOT envisions a more strategic program based on the asset management principles and techniques promoted in this TAMP.

PAVEMENTS

MnDOT's Highway Pavement Management Application (HPMA – discussed in **Chapter 5**) was used to determine the investment needs and outcomes developed for MnSHIP. A conceptual model of typical pavement deterioration is shown in **Figure 8-7**.

Figure 8-7: Conceptual Model of Pavement Deterioration

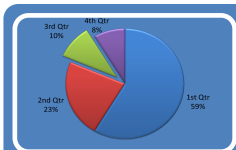


Though it is well understood that investments in preservation early in a pavement's life-cycle will provide a good return on investment, there are other tradeoffs to be considered when developing a balanced investment plan:

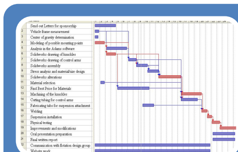
- **Constrained Budget:** Because MnDOT is working with a constrained budget and the fact that maintaining a road in Good condition is most cost-effective (see **Chapter 6**), investments are made to keep as many of the roads in Good condition as possible. This is done through the application of maintenance and preservation treatments for roads in Good and Fair condition and through major rehabilitation and reconstruction activities for pavements in Poor condition. Selection of individual project is based on several factors: average daily traffic (ADT), safety, the economic importance of the highway corridor, public perception, and customer satisfaction.
- **Pavement Age and Condition:** Approximately 50 percent of Minnesota's state highways are over 50 years old, which means that a high percentage of the pavement network will not benefit from preservation treatments; these roads are in need of more substantial rehabilitation or reconstruction. Care should be taken to apply the right type of treatment to the right asset. Pavements are rated based on their vehicle ride quality (see **Chapter 3**). Those with an RQI below 2.0 are typically candidates for major rehabilitation and reconstruction. Routine patching has been identified as a suitable maintenance operation for pavements that have an RQI of 3.2 or higher.
- **Length of Pavement Segment:** When selecting pavement projects, standard MnDOT practice is to combine several adjacent segments and construct one large project rather than doing short stretches; mobilization and logistical costs become expensive for small-scale projects.
- **Performance Targets:** To meet established performance targets, a good portion of the investment has to be made in major rehabilitation and reconstruction activities, which tend to have a greater effect on overall network condition when compared to maintenance and preservation activities.
- **Pavement Preventive Maintenance:** MnDOT districts use this capital setaside to fund maintenance activities between major pavement rehabilitation projects in order to help manage pavements at the district level. MnDOT's pavement model assumes that preventive maintenance activities are being addressed.

Between 2014 and 2023, MnDOT identifies capital pavement expenditures of $392 million on Interstate pavements, $1.13 billion on the non-Interstate NHS and $1.38 billion on the non-NHS system, for a total of $2.90 billion. Investments in pavement preservation and operational/routine maintenance will total approximately $35-40 million annually (based on data from 2003 to 2012, provided by the Pavement Work Group). Conditions on NHS pavements will remain stable through 2023. In particular, fewer Interstate pavements will be in Poor condition relative to today. However, the condition of pavements on non-NHS roads will see a drop in performance, in large part to accommodate the federal emphasis on higher-volume NHS roads. The typical strategy used by MnDOT to develop investment levels for pavements is summarized in **Figure 8-8**.

Figure 8-8: MnDOT Typical Preventive/Corrective Actions Investment Strategy for Pavements



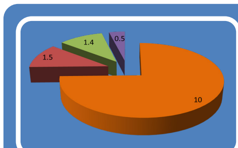
Determine initial fraction of statewide system in Good, Fair and Poor conditions



Using a constrained funding level, determine the amount of major rehabilitation and preventive maintenance work required of meet targets

Develop a candidate list of sections for rehabilitation and preventive maintenance to meet targets

- NHS projects are managed through the centrally (at a statewide level)
- Non-NHS projects are managed at the district level



Determine a revised fraction of sections in Good, Fair, and Poor conditions if the candidate sections in step 2 have been addressed

Overall, MnDOT expects projected pavement condition levels to meet assumed MAP-21 requirements and GASB 34 thresholds through 2023. Planned conditions for 2023 are: 2 percent of Interstate pavements in Poor condition, 4 percent of non-Interstate NHS pavements in Poor condition, and 12 percent of non-NHS pavement in Poor condition.

PAVEMENT OPTIMIZATION STRATEGIES

MnDOT will continue applying the following strategies to make the best use of resources when undertaking pavement projects:

- Design and schedule pavement projects to align with a roadway's life-cycle needs whenever possible.
- Use performance-based design to focus on projects that cost-effectively meet both pavement and safety performance needs.
- Continue preventive maintenance strategies, such as seal coats, joint seals, micro-surfacing, and thin overlays.
- Employ lower-cost long-term strategies, such as full depth reclamation or unbonded concrete overlays, to further stretch available dollars.
- Evaluate innovative contracting methods and assess potential advantages of bundling projects in order to lower costs.

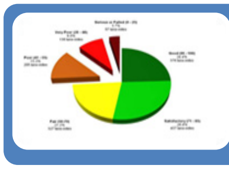
BRIDGES

Investment needs and outcomes for bridges were established using MnDOT's Pontis bridge management system for bridge inventory and condition data, and MnDOT's Bridge Replacement and Improvement Management System (BRIM) for prioritization and cost estimates. BRIM currently places an emphasis on rehabilitation and replacement, but there is an upgrade underway that will better link preventive activities to capital improvements.

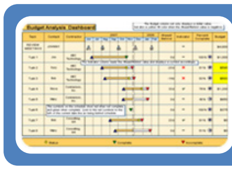
The life-cycle of a bridge offers multiple opportunities for maintenance and life extension. Deterioration from age, traffic, and chemicals is constantly at work to reduce the condition of bridges. Routine maintenance work tends to slow the rate of deterioration, but does not prevent damage from eventually taking place. If timely mid-life repairs are made, conditions can be improved, thus extending the lifespan. Eventually, age and deferred maintenance cause a bridge to slip into a structurally deficient state where only expensive rehabilitation and replacement can restore the needed level of performance.

Approximately $10-15 million is spent each year on routine bridge maintenance and bridge preservation using funds from the operations and maintenance budget. The size of this budget is based on management experience rather than objective analysis. Mid-asset-life preservation actions can be funded from either the operations or the capital budget, depending on the magnitude of the work. This category of work is under-funded and would benefit from improved planning tools to correctly size the budget, select the best candidates for this activity, and produce a more balanced investment plan. The typical strategy used by MnDOT to develop investment levels for bridges is summarized in **Figure 8-9**.

Figure 8-9: MnDOT Typical Preventive/Corrective Actions Investment Strategy for Bridges



Determine initial fraction of bridges in Good, Fair and Poor conditions



Plan and prioritize investments with a risk-based approach.

The primary goal is to meet bridge performance targets (through major rehabilitation) while making appropriate investments on the right type of treatment for the right candidates.

Proactively schedule preventive maintenance and minor repairs to maximize the useful life of bridges and slow rates of deterioration

Invest in larger rehabilitation efforts to improve condition and restore bridge function to acceptable levels

For years 2014-2023, MnDOT envisions capital bridge expenditures of $1.10 billion on the NHS and $48 million on non-NHS bridges, for a total of $1.58 billion. Condition of bridges on the NHS will improve overall, while condition on non-NHS bridges will worsen, but the overall condition of MnDOT bridges is expected to meet or nearly meet performance targets through 2023. As noted previously (and below), MnDOT's bridge condition targets state that no more than two percent of NHS bridge deck area and eight percent of non-NHS bridge deck area should be in Poor condition.

BRIDGE OPTIMIZATION STRATEGIES

MnDOT will apply the following strategies to ensure that its bridges are structurally sound and safe for the traveling public:

- Conduct frequent and regular inspections.
- Invest in preventive maintenance.
- Invest in rehabilitation at appropriate times in a bridge's life-cycle.
- Refine BRIM to help identify improvements that minimize life-cycle costs, meet performance targets, and address the highest-risk bridges.
- Defer some long-term fixes and impose occasional weight restrictions to avoid hazardous conditions, as needed.

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS

MnSHIP does not break out the asset categories within the Roadside Infrastructure investment category, but culverts make up the largest portion of this cost. Approximately $300 million is included for capital funding of culvert work through 2023. HSOP also includes approximately $10 million annually for all drainage maintenance, which includes money spent on both highway culverts and deep stormwater tunnels.

Improved programs for flushing, inspection, and repair of culverts would increase the necessary amount of capital and maintenance funding to a total of $400 million over the 10 year period, with an additional $37 million needed for deep stormwater tunnels, given the targets recommended in **Chapter 7** (and below).

OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES

In recent years, MnDOT has spent approximately $500,000 annually to maintain overhead sign structures and high-mast light tower structures. These structures exhibit long service lives with minimal maintenance. Their primary modes of failure include wind-induced vibration, fatigue cracking of structural components, corrosion, and collapse of structural support systems. MnDOT has not observed any catastrophic failures of these assets; if the structure was initially installed according to specifications, it seldom exhibits premature component failure. This has been the primary driver for instituting a change in the structure installation specifications (discussed in **Chapter 6** and **Chapter 7**).

The investment strategy for overhead sign structures and high-mast light tower structures has been developed using an approach that considers the fraction of structures with various condition levels and makes a balanced investment according to expert input. For the 10 years from 2014 to 2023, MnDOT envisions capital and maintenance expenditures of $8 million for overhead sign structures. An investment need could not be determined for high-mast light tower structures due to insufficient condition data; this will be revisited in the near future.

MnSHIP also outlines several strategies to maximize future Roadside Infrastructure Condition investment:

- Continue to perform preventive maintenance to extend infrastructure life.
- Coordinate investments with other projects where economies of scale exist to reduce unit costs.
- Manage culverts that have failed or are in the poorest conditions.
- Maintain the most critical supporting infrastructure for pavement and bridge projects.

Summary

Figure 8-10 summarizes planned 10-year capital investments (from MnSHIP) to achieve pavement and bridge targets, as well as investments needed to achieve highway culvert, deep stormwater tunnel, overhead sign structure, and high-mast light tower structure targets.

Figure 8-10: Targets and Planned or Needed Investment to Achieve Targets

ASSET	CURRENT CONDITION	TARGET RECOMMENDATION	INVESTMENT*
Pavement: Interstate	2.4% Poor	≤ 2% Poor	$392 million
Pavement: Non-Interstate NHS	4.3% Poor	≤ 4% Poor	$1.13 billion
Pavement: Non-NHS	7.5% Poor	≤ 10% Poor	$1.38 billion
Pavement: Total	**NA**	**NA**	**$2.9 billion**
Bridge: NHS	4.7% Poor	≤ 2% Poor	$1.10 billion
Bridge: Non-NHS	2.1% Poor	≤ 8% Poor	$430 million
Bridge: Total	**NA**	**NA**	**$1.53 billion**
Hydraulic Infrastructure: Highway Culverts	10% Poor; 6% Very Poor	≤ 8% Poor; ≤ 3% Very Poor	$ 400 million
Hydraulic Infrastructure: Deep Stormwater Tunnels	39% Poor; 14% Very Poor	≤ 8% Poor; ≤ 3% Very Poor	$ 35 million (condition) + $1.6 million (inspection)
Other Traffic Structures: Overhead Sign Structures	6% Poor; 8% Very Poor	≤ 4% Poor; ≤ 2% Very Poor	$8 million
Other Traffic Structures: High-Mast Light Tower Structures	6% Poor; 15% Very Poor	TBD	TBD

*Pavement and bridge figures represent 10 year planned investment to meet targets; hydraulic Infrastructure and other traffic structures figures represent 10 year needed investment to meet targets.

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Chapter 9

IMPLEMENTATION AND FUTURE DEVELOPMENTS

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IMPLEMENTATION AND FUTURE DEVELOPMENTS

Overview

An effective Transportation Asset Management Plan will require regular updates to reflect the dynamic nature of managing a transportation network. For MnDOT, efficient asset management is an established objective within existing policy, investment, and operations plans. Therefore, success will be largely determined by the extent to which the principles and initiatives outlined in this document are incorporated, along with existing plans, into MnDOT's business practices. This final chapter outlines MnDOT's governance approach moving forward, summarizes implementation priorities, and concludes with a set of "lessons learned" during the development of the plan.

TAMP Governance

In accordance with MAP-21, the TAMP development process must be reviewed by the FHWA and certified as meeting the requirements established by the Secretary of Transportation. The process used to develop and maintain the TAMP must be reviewed and recertified at least once every four years; FHWA will identify specific actions that are necessary to correct any deficiencies. Additionally, MAP-21 requires that states make significant progress toward achieving their targets for the National Highway System.

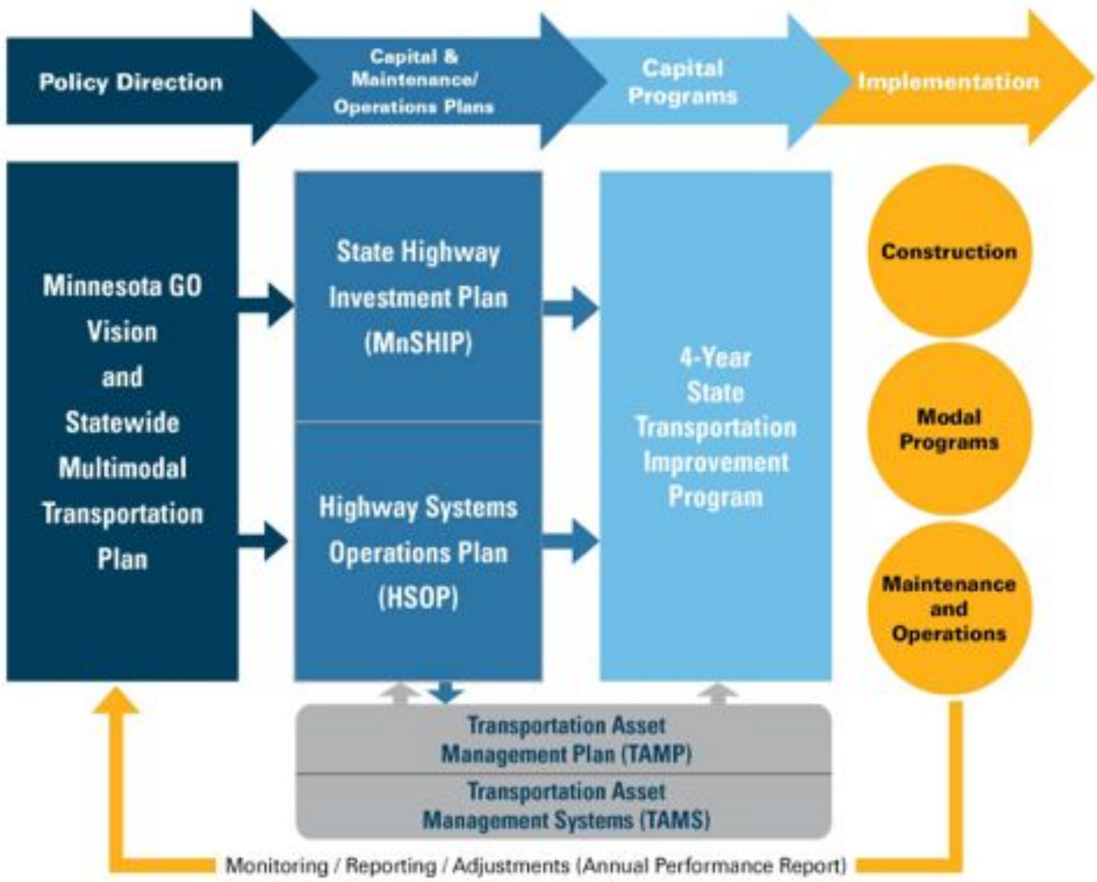
While meeting federal requirements was certainly an objective, MnDOT's primary focus in developing this plan has been to improve the life-cycle management of its transportation assets. Therefore, governance responsibilities must be extended beyond those required under the legislation. They must include plans for expanding the assets that are covered in future TAMPs and for monitoring the agency's success. It was recommended that an Asset Management Steering Committee be established and assigned responsibility for the development, update, and monitoring of the enhancements outlined in the TAMP, and oversight of Transportation Asset Management System (TAMS) development and other asset management initiatives. The Steering Committee will be championed by MnDOT's Modal Planning and Program Management, Engineering Services, and Operations Division Directors, and include representatives from Engineering Services, Transportation System Management, and Operations and Maintenance. Direct communication with Finance; Districts; Traffic, Safety, and Technology; Materials; Bridge; and other asset categories will be important. The Steering Committee will report directly to the Division Director champions and MnDOT's Senior Leadership Team, and meet on a regular basis to address the following:

- Modifying the draft TAMP to address any requirements outlined in the final rules issued by the Secretary of Transportation
- Establishing a regular cycle for updating the TAMP in conjunction with updates to MnSHIP and other relevant documents
- Developing and implementing guidance for expanding the TAMP to include other transportation assets; this guidance should include factors such as:
- Availability of data
- Overall maturity of business processes to support management of the asset
- Importance of preservation actions to maintain the asset
- Funds spent on the asset
- Level of risk associated with asset failure
- Monitoring progress toward performance targets and recommending adjustments

In addition to having responsibility for governance of the TAMP, the Steering Committee would also be assigned responsibility for ensuring that the asset management principles promoted in the TAMP are fully embraced at all levels of the agency to help ensure that the anticipated performance outcomes are met. This will require clear lines of responsibility and accountability for each of the assets included in the TAMP and an agency-wide commitment to completing scheduled inspections for highway culverts, overhead sign structures, and high-mast light tower structures. It will also necessitate timely application of preservation treatments by each district and other strategies to reduce the overall life-cycle cost of managing MnDOT's transportation assets.

The Steering Commitee would also work with several units of the Office of Transportation System Management and the larger Modal Planning and Program Management Division to coordinate the next update to MnSHIP, ensuring that the TAMP recommendations are used to drive future investment plans. The interrelationship between the TAMP and other MnSHIP planning and programming products is shown in **Figure 9-1**. As shown in the graphic (and discussed in **Chapter 2**), the TAMP serves as a link between the long-term statewide plans (such as MnSHIP) and the projects programmed into the STIP and Annual Work Plans.

Figure 9-1: Links between MnDOT Planning and Programming Processes



Implementation Priorities

PRIORITIES IDENTIFIED THROUGH RISK PROCESS

Chapter 5 of this plan explored the concept of risk as it relates to transportation, as it influences planning and management at MnDOT, and as it was incorporated into the TAMP. It also presented a series of prioritized strategies intended to help mitigate identified undermanaged risks – areas in which there are clear opportunities for improvement at MnDOT (see **Technical Guide** for more on the prioritization process). **Figure 9-2** offers more detail on these strategies, including responsible offices, expected timeframes, and estimated implementation costs.

Timeframes and costs were estimated by the TAMP Work Groups but could not be determined with certainty for several of the strategies.

Figure 9-2: Prioritized Strategies for Mitigating Undermanaged Risks

PRIORITY LEVEL 1 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIMEFRAME	ESTIMATED COST
Annually track, monitor, and identify **road segments** that have been in Poor condition for more than five years and consistently consider them when programming.	To provide additional information when prioritizing projects; to highlight roads that have been in Poor condition for an extended period of time; to help MnDOT improve level of service for customers statewide	MnDOT Materials Office	1-2 years (to develop)	Approximately $5 thousand (staff time)
Address the repairs needed on the existing South I-35W **deep stormwater tunnel** system.	To improve condition of South I-35W deep stormwater tunnel; to alleviate safety concerns and reduce overall percentage of deep stormwater tunnel system in Poor and Very Poor condition (thereby helping MnDOT meet targets)	MnDOT Metro District; City of Minneapolis	1-2 years (currently programmed)	Approximately $14.5 million (for repairs; funded)
Investigate the likelihood and impact of **deep stormwater tunnel** system failure.	To improve understanding of the likelihood for failure of the deep stormwater tunnel system (located entirely in MnDOT's Metro District) and the likely impacts of such an event; to aid planning and management of the system	MnDOT Bridge Office; MnDOT Metro District	1-3 years	Approximately $150 thousand (for study)
Develop a thorough methodology for monitoring **highway culvert** performance.	To increase availability of information; to develop a systematic and objective methodology to monitor culverts; to manage culverts more effectively	MnDOT Operations	1-2 years (currently underway)	$5-10 thousand (to develop procedures)

Develop and adequately communicate construction specifications for **overhead sign structures** and **high-mast light tower structures**.	To prevent installation problems that lead to premature deterioration and reduced asset life; to ensure that MnDOT inspectors and vendors understand and adhere to requirements (e.g. torque thresholds)	MnDOT Maintenance – Metro District; MnDOT Maintenance – Other Districts	1 year	Approximately $50 thousand (to develop and implement)
Track **overhead sign structures** and **high-mast light tower structures** in a Transportation Asset Management System (TAMS).	To more deliberately and effectively manage these asset categories; to include more assets in TAMS, thereby improving cross-asset tradeoff decision-making	MnDOT Office of Transp. System Management; MnDOT Metro District	2-4 years	TBD
PRIORITY LEVEL 2 STRATEGY	**PURPOSE(S)**	**RESPONSIBLE OFFICE**	**EXPECTED TIMEFRAME**	**ESTIMATED COST**
Collect and evaluate performance data on ramps, auxiliary lanes, and frontage **road pavements** for the highway system in the Twin Cities Metro Area.	To determine current inspection procedure is sufficiently capturing needs; to more effectively manage non-mainline highway pavements	MnDOT Metro District; MnDOT Materials Office	1-3 years	Approximately $200 thousand (for data collection/ analysis)
Augment investment in **bridge** maintenance modules and develop related measures and tools for reporting and analysis.	To develop performance models to predict changes in bridge performance over time; to more effectively manage bridges	MnDOT Bridge Office	1-3 years (currently underway)	Approximately $2 million (software upgrades; funded)
Include **highway culverts** in MnDOT's TAMS.	To more deliberately and effectively manage highway culverts; to include more assets in TAMS, thereby improving cross-asset tradeoff decision-making	MnDOT Bridge Office	2-4 years	TBD
Place pressure transducers in **deep stormwater tunnels** with capacity issues.	To place pressure transducers in deep stormwater tunnels that will collect better capacity-specific data such as pressure impact by water volume	MnDOT Metro District	1-2 years	Approximately $50 thousand

Incorporate the **deep stormwater tunnel** system into the bridge inventory.	To improve regularity of deep stormwater tunnel inspections by adding the tunnel system to the bridge inventory, with inspection frequency tied to reported condition	MnDOT Metro District; MnDOT Bridge Office	1-2 years	TBD
Develop a policy requiring a five-year inspection frequency for **overhead sign structures**, as well as related inspection training programs and forms.	To establish a formal inspection program for overhead sign structures, based on MnDOT's best knowledge of structure condition, deterioration rates, and inspection needs	MnDOT Maintenance – Metro District; MnDOT Maintenance – Other Districts	1 year (currently underway)	$150 thousand (staff time)
PRIORITY LEVEL 3 STRATEGY	**PURPOSE(S)**	**RESPONSIBLE OFFICE**	**EXPECTED TIMEFRAME**	**ESTIMATED COST**
Repair or replace **highway culverts** in accordance with recommendations from the TAMS (once it is implemented).	To improve overall system quality and management; to meet newly established and vetted asset targets	MnDOT Maintenance – Various Districts; MnDOT Bridge Office	10 years	$100 million ($10 million per year)

OTHER PRIORITIES IDENTIFIED DURING TAMP DEVELOPMENT

To further improve its overall asset management practices and achieve lowest life-cycle cost, MnDOT considered factors beyond risk during development of the TAMP. As a result, several overarching business process enhancements have been proposed and are summarized in **Figure 9-3**. Timeframes and costs for these broad improvements have not been estimated.

Figure 9-3: Planned Changes to MnDOT Business Processes

PRIORITY	PURPOSE(S)	RESPONSIBLE PARTY
Establish a single process governing the development of all MnDOT performance measures and targets. Incorporate process into MnDOT's performance-based planning framework.	To promote a consistent approach to performance measurement that is in line with traveler expectations and MnDOT's strategic direction; to provide a mechanism for acting on target recommendations provided in this TAMP	Performance, Risk and Investment Analysis Unit (MnDOT Office of Transportation System Management)
Implement strategies that reduce life-cycle costs for managing assets.	To improve consideration of total cost of ownership in capital investment decisions, including tracking preventive maintenance activities; to re-scope projects to realize life-cycle cost savings (candidate for Investment Opportunity Plan)	MnDOT Office of Transportation System Management
Identify new operational performance targets and reporting protocols covering preventive maintenance.	To ensure that asset-specific preservation activities are being completed on a timely basis; to regularly monitor progress and assess achievement	Asset Management Steering Committee; Operations Division; Materials Office
Evaluate investment impacts across asset categories.	To improve cross-asset decision-making processes by integrating tradeoff analyses (more comprehensive tradeoff analyses will be possible as asset registers and risk assessments are completed for additional asset categories)	MnDOT Office of Transportation System Management
Shift to a corridor management approach.	To more comprehensively consider safety, mobility, and preservation needs when making investment decisions; to select projects based on more than just pavement and bridge conditions	MnDOT (agency-wide)

RESEARCH PRIORITIES

Along with risk-based strategies and overall business process enhancement recommendations, the development of this TAMP illuminated a number of research needs. Such applied research would help MnDOT better understand asset performance and would lead to more informed investment decision-making. These research opportunities could be addressed via formal research studies or by program offices using data available to them. Identified research needs include:

- Overall
- Development of robust asset-specific or network-level deterioration models (for each material type used, if possible)
- Investigation of return-on-investment associated with capital and maintenance expenditures (the probabilities and impacts of not investing in assets are poorly understood)
- Pavements
- Better understanding of performance and benefit-costs of pavement preservation treatments applied in Minnesota
- Improved analysis of maintenance cost data for use in life-cycle costing
- Better understanding of performance of pavement rehabilitation activities (structural overlays, full depth reclamation, etc.) in relation to pavement age and condition
- Bridges
- More complete understanding of bridge performance by type of material (steel, concrete, timber, etc.)
- Better understanding of impact of routine maintenance activities on bridge performance and life-cycle costs
- Hydraulic Infrastructure
- Development of deterioration models for various types of culverts and tunnels
- Better understanding of impacts of various maintenance treatments
- Overhead Sign Structures and High-Mast Light Tower Structures

- Development of deterioration models and more accurate average service life
- Better understanding of impacts of various treatments performed on these structures in varying ages and conditions

Recommended Targets

Another important result of this TAMP development is the establishment of condition targets for asset categories or sub-categories not explicitly addressed in MnSHIP. A summary of these Work Group-developed and Steering Committee-vetted targets is included at the end of the previous chapter (**Figure 8-10**). Many of the implementation priorities discussed in **Figure 9-2** and **Figure 9-3** will directly or indirectly contribute to MnDOT achieving these targets within 10 years (and sustaining them thereafter). For a more detailed discussion the recommended condition targets, see **Chapter 8: Financial Plan and Investment Strategies**.

Lessons Learned

The TAMP development process was beneficial in that it helped formally document the asset management procedures currently being used at MnDOT for managing pavements and bridges. These existing procedures provided a framework for managing additional roadside assets now and in the future. As a result of the TAMP process, MnDOT also has a better understanding of the risks associated with undermanaged assets and is poised to improve many of its business processes.

As other states begin development of their own asset management plans, they may benefit from the following lessons learned during MnDOT's TAMP development process.

1. MnDOT has strong pavement and bridge management programs in place that have been used for years to support agency planning and programming activities. However, even with strong programs in place, several business process improvements were identified that will further strengthen the programs. The development of the TAMP also helped justify improvements that were already underway, such as completing bridge management tools to improve predictions of future conditions and formalizing the inspection of overhead sign structures and high-mast light tower structures to help reduce the risk of failure. For assets without formal management processes in place, such as overhead sign structures, high-mast light tower structures, highway culverts, and stormwater tunnels, the TAMP framework served as a proof-of-concept for expanding the scope of future TAMPs.

2. The process of using existing data to develop the TAMP provided insight into the completeness and reliability of the data and a better understanding of the risks associated with undermanaging the assets. For example, the potential risk of failure associated with the I-35W South deep stormwater tunnel contributed to MnDOT programming $12 million to address needed repairs. Similarly, the plan led to the observation that there are many miles of access roads, ramps, frontage roads, and auxiliary lanes that are not currently being monitored and tracked.

3. Evaluating the life-cycle cost of overhead sign structures led to the observation that most performance issues were related to inadequate construction practices (loose nuts). As a result, new design standards were initiated to eliminate this issue from occurring in the future.

4. MnDOT has a risk management framework for managing agency risks effectively at the enterprise level. By focusing on risks associated with achieving the performance outcomes documented in the TAMP, MnDOT was able to uncover risks associated with undermanaging assets that had not previously been at the forefront, such as the need for prediction models to better manage bridges and the need for a formal inspection process for overhead sign structures and high-mast light tower structures.

5. The multi-disciplinary nature of the Steering Committee and the Project Management Team served MnDOT well because of the different perspectives it provided. Similarly, the formation of the technical Work Groups was instrumental in providing the content required to complete the TAMP. Therefore, the breadth of the team is important to provide guidance, but the technical nature of the TAMP content requires input from in-house technical specialists.

6. The TAMP is intended to provide upper management, elected officials, and the public with a summary of the plans for managing existing transportation assets over a 10 year period. Therefore, the TAMP needs to be written at a fairly high level. However, there is a lot of documentation that should be captured as part of the development process and MnDOT elected to capture that documentation in a separate Technical Guide document that can serve as a reference during future TAMP updates.

Moving Forward

The development of MnDOT's first TAMP has already begun to improve and refine many aspects of the agency's policies and methods related to asset management. By demonstrating the value of life-cycle costing, the TAMP will have a positive effect on future investment decision-making. In addition, the TAMP development process focused attention on data gaps that exist at the agency and led to initiatives aimed at improving the sophistication of data collection and analysis methods. MnDOT plans to continue moving forward with asset management planning in the coming years, with each new task building on previous work and adding additional asset categories, increasing the breadth and precision of data available to decision makers. These and similar actions will help MnDOT achieve its overarching goal of enhancing financial effectiveness. When combined with the forthcoming Transportation Asset Management System (TAMS, see **Chapter 2**), the TAMPs will help guide and improve policy and programming decisions at MnDOT, leading to more efficient and effective management of infrastructure assets and helping the agency meet the high standard of service expected by all Minnesotans.

We all have a stake in A to B

Transportation Asset Management Plan

Technical Guide

July 2014

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MinnesotaGO

A Collaborative Vision for Transportation

Purpose and Structure of the TAMP Technical Guide

PURPOSE AND STRUCTURE OF THE TAMP TECHNICAL GUIDE

Purpose and Scope

The TAMP Technical Guide provides further detail on the process, methodology, and analyses conducted during the development of the TAMP. While all the information contained in the Technical Guide is relevant and may be of interest to those tasked with developing a TAMP, much of the information was considered too detailed for inclusion in the main document (in that it could potentially disrupt the flow for the reader). Therefore, this Technical Guide was developed to document such details and to serve as a reference for updates to the TAMP.

Structure

The TAMP Technical Guide has been designed to roughly parallel the main TAMP, with eight chapters (in addition to this Introductory chapter), each corresponding to a chapter in the TAMP and following a general format with two key sections:

- A **Process** section, with a narrative describing the processes MnDOT went through to develop each chapter of the TAMP, including the analyses and the methods of gathering the required information (with visual aids, as necessary)
- A **Supporting Documentation/Data** section, which highlights and explains the data, analyses, and results (including displays of spreadsheets and worksheets, as applicable)

Depending on the nature of the corresponding TAMP chapter, some Technical Guide chapters are weighted more toward process, while others contain more supporting documentation/data. Several (Chapters 3 and 7) are quite short due to the comprehensiveness of their parallel TAMP chapters.

- **Chapter 1(Introduction) and 2 (Asset Management Planning and Programming Framework)** – Supplemental Information
  - This chapter provides a narrative on the process of developing MnDOT's first TAMP, including details regarding the workshops and other necessary meetings. A table is provided that maps each MAP-21 requirement to the chapter in which it appears in MnDOT's TAMP.
- **Chapter 3 (Asset Management Performance Measures and Targets)** – Supplemental Information
  - Chapter 3 of the TAMP contains information pertaining to asset management performance measures and targets. Key terms associated with targets discussed in the TAMP are the focus of this chapter of the Technical Guide.
- **Chapter 4 (Asset Inventory and Conditions)** – Supplemental Information
  - This chapter describes the steps involved in assembling the asset register/folios. Also discussed are key issues in finalizing the folios for the TAMP and general procedures to update and maintain the asset register/folios.
- **Chapter 5 (Risk Management Analysis)** – Supplemental Information
  - This chapter provides a detailed description of the various processes involved in identifying and prioritizing the risks and mitigation strategies described in the TAMP. MnDOT's approach to Enterprise Risk Management is presented in this chapter, along with the steps involved in determining the undermanaged risks presented in the TAMP.
- **Chapter 6 (Life-Cycle Cost Considerations)** – Supplemental Information
  - This chapter provides a detailed description of the various processes involved in analyzing the life-cycle costs associated with the asset categories discussed in the TAMP. Two separate aspects of life-cycle costing are documented: 1) the data used to conduct the analysis and the process for gathering the information; and 2) the metrics and assumptions used in the analysis.
- **Chapter 7 (Performance Gaps)** – Supplemental Information
  - Chapter 7 contains information pertaining to current and targeted performance levels. This Technical Guide chapter provides a brief overview of how performance gaps are discussed in the TAMP.

- **Chapter 8 (Financial Plan and Investment Strategies)** – Supplemental Information
  - This chapter provides a description of the asset management investment strategies developed as a part of the Minnesota State Highway Investment Plan (MnSHIP) and how they were incorporated into the TAMP. The investment strategies developed for highway culverts, stormwater tunnels, overhead sign structures and high-mast light tower structures are discussed in greater detail than in the main TAMP document. A summary is also included that details the envisioned process changes regarding how future TAMPs will inform MnSHIP updates.
- **Chapter 9 (Implementation and Future Developments)** – Supplemental Information
  - This chapter describes a process to help MnDOT decide which assets to consider adding in its next TAMP. A few asset management tools and techniques that MnDOT could potentially implement in the future are also discussed.

Chapter 1

INTRODUCTION:
SUPPLEMENTAL INFORMATION

AND

Chapter 2

ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK:
SUPPLEMENTAL INFORMATION

INTRODUCTION AND ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK: SUPPLEMENTAL INFORMATION

Overview

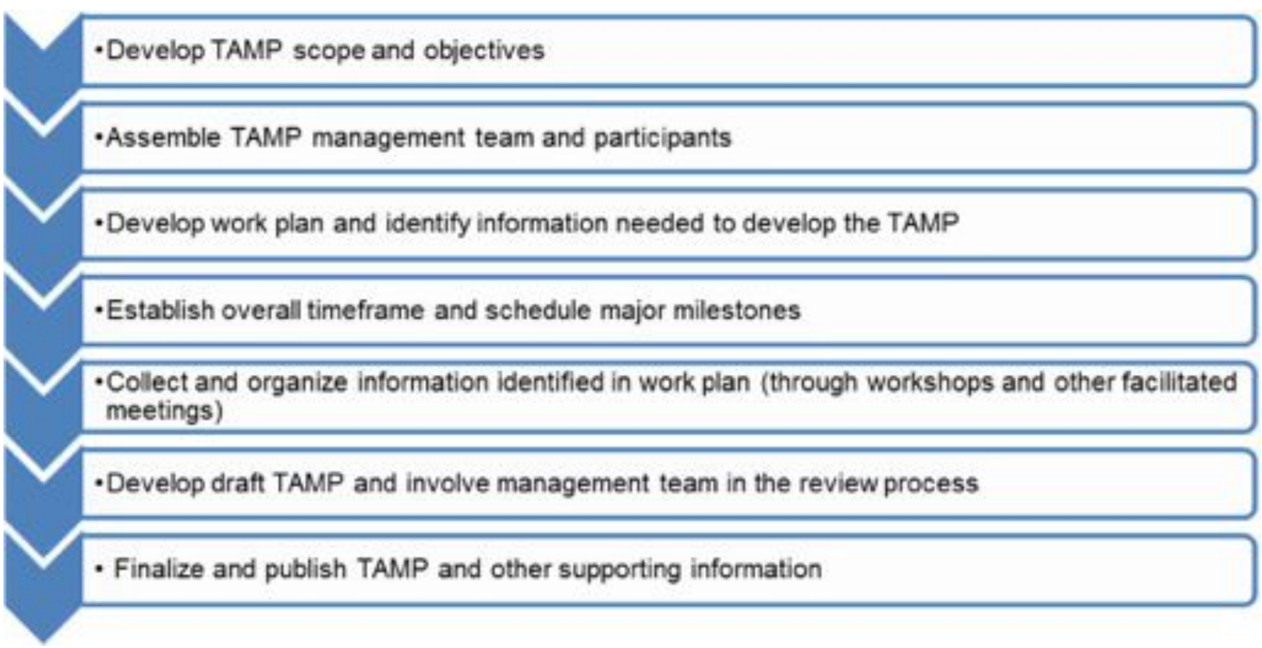
This chapter provides a narrative of the process for the development of MnDOT's first TAMP. Details are provided regarding the basic processes used to develop each section of the TAMP and the face-to-face meetings held to discuss results and findings at each stage of the TAMP development process. A simple table (Figure 1-4) is also provided that discusses MAP-21 requirements and the section of the TAMP that addresses those requirements.

Note:
Chapter 2 of the TAMP provides the necessary documentation regarding MnDOT's planning and programming framework. Therefore, the primary focus of this chapter of the Technical Guide is supplementary information pertaining to the TAMP development process.

Process

This section describes the basic processes involved in developing the TAMP, including the roles and responsibilities of various personnel and groups involved. The critical pieces of information required to develop the TAMP are also highlighted, in addition to the various meetings and facilitated workshops conducted during the TAMP development process. The overall TAMP development process flow is illustrated in Figure 1-1.

Figure 1-1: TAMP Development Process



TAMP SCOPE

The MnDOT TAMP formalized and documented key information on the following six asset categories:

- Pavements
- Bridges
- Highway Culverts
- Deep Stormwater Tunnels
- Overhead Sign Structures
- High-Mast Light Tower Structures

For each asset class, the following information was incorporated into the TAMP:

- Asset inventory and conditions
- Asset management objectives and measures
- Performance gap assessment
- Life-cycle cost (LCC) considerations
- Risk management analysis
- Financial plan and investment strategies
- Asset management process enhancements

TAMP DEVELOPMENT MANAGEMENT AND TIMEFRAME

The development of MnDOT's TAMP was led by Mr. Mark Nelson, Mr. Kirby Becker, and Mr. Matthew Malecha from MnDOT's Office of Transportation System Management. Mr. Nelson served as the contact for the FHWA pilot study and Mr. Becker and Mr. Malecha served as Project Managers for the consulting contract with Applied Pavement Technology, Inc. (APTech). The TAMP development effort commenced in June 2013 and a final version of the TAMP was completed in July 2014.

PARTICIPANTS IN DEVELOPING THE TAMP

The TAMP was developed through the cooperative efforts of several committees, Work Groups, and outside contractors, as described below.

STEERING COMMITTEE

The Steering Committee provided general direction to the TAMP effort and assisted in communicating the purpose and progress to other stakeholders. The Steering Committee met every other month (six times) during development of the TAMP to provide direction on risk, life-cycle cost, performance measures and targets, financial plan and strategies, and next steps.

PROJECT MANAGEMENT TEAM

A multi-disciplinary Project Management Team (PMT) managed the overall TAMP effort and was very involved in project management tasks, such as work plan development. The PMT also collaborated with the outside contractors on a regular basis and served as members of the technical Work Groups. Similar to the Steering Committee, the PMT met every other month (six times) during development of the TAMP. Members on the PMTalso served on the Steering Committee.

WORK GROUPS

Work Groups were developed for each specific asset category and a separate Work Group to help facilitate the risk assessment and management process. These groups assisted in documenting current practices in terms of risk management, life-cycle costing, gap identification, and financial planning. The groups also helped develop and review defined levels of service, performance measures and targets, and maintenance and capital cost estimates for identified asset categories. During development of the TAMP, there were more than twenty Work Group meetings to discuss the above information.

FHWA PILOT STUDY SUPPORT

The FHWA Office of Asset Management supported three state DOTs in a pilot project to develop their first TAMPs, which will serve as models to be studied and as examples for other state or local transportation agencies. Along with MnDOT, agencies participating in the TAMP pilot were the Louisiana Department of Transportation and Development (LADOTD) and the New York State Department of Transportation (NYSDOT).

The contractor for the FHWA pilot project was AMEC, with technical assistance from Cambridge Systematics. The FHWA contractor was responsible for providing technical assistance to and helping to develop TAMPs for the three pilot states. Key contacts for the AMEC/Cambridge Systematics team include Mr. Jonathan Groeger, AMEC, and Mr. Joe Guerre, Cambridge Systematics.

MNDOT CONTRACTOR SUPPORT

MnDOT contracted with Applied Pavement Technology, Inc. (APTech) to assist with the development of MnDOT's comprehensive TAMP. As part of the contract, APTech, in coordination with MnDOT facilitated meetings of the PMT, Steering Committee, and Work Groups and assisted with the development of a comprehensive TAMP and a corresponding Technical Guide. Ms. Katie Zimmerman was the Principal Investigator for APTech. She was assisted by Mr. Prashant Ram, APTech, and Mr. Paul Thompson, an individual consultant to the team.

INFORMATION NEEDED TO DEVELOP THE TAMP

Figure 1-2 summarizes the key information and work activities required to develop the TAMP. Much of the information was obtained through facilitated teleconferences, Work Group assignments, and face-to-face meetings/workshops with the participants involved in the TAMP development process.

Figure 1-2: Information Needed to Develop the TAMP

SECTION	INFORMATION/WORK ACTIVITIES REQUIRED
Asset Management Planning and Programming Framework	• Describe the objectives of the asset management program. • Describe existing asset management policy and various plans and programs currently in place to support asset management. • Discuss MnDOT's overall capital and operations/maintenance investment priorities. • Document the process used to develop the above items.
Asset Management Performance Measures and Targets	• Summarize the performance measures and targets documented to be used in the TAMP. • Assess the adequacy of the performance measures to make investment decisions and make any recommendations for changes. • Determine whether any additional performance measures are needed to report progress towards national goal areas. • Document the process for developing performance measures and establishing performance targets. • Recommend to the Steering Committee any changes to performance measures that might be required. • Document the process for using performance data to support asset management investment decisions at MnDOT.

Asset Inventory and Condition	• Develop an asset register showing the inventory count of each asset, current replacement value, current age and condition, office responsible for the data, and confidence in the data. • Compile documentation on the procedures used to assess asset condition.
Risk Management Analysis	• Describe MnDOT's process for assessing and managing risks. • Document agency and program risks that could impact MnDOT's ability to achieve the goals documented in the TAMP. • Summarize agency and program risks in a risk register that includes the likelihood and consequences of occurrence and recommendations for mitigation. • Document the process used to evaluate risks.
Life-Cycle Cost Considerations	• Describe "life-cycle costs" and explain why they are important. • Provide an example of a typical deterioration model. • Describe strategies for managing assets over their whole lives, from inception to disposal, illustrating the use of a sequence of activities including maintenance and preservation treatments. • Document the typical life-cycle cost of the assets included in the TAMP. • Document the typical life-cycle cost of adding a new lane-mile of roadway and document a process for considering future maintenance costs when evaluating potential roadway expansion projects. • Document the tools used by the agency to manage assets effectively over their life-cycles.
Performance Gaps	• Describe short- and long-term asset management planning horizons. At a minimum, the TAMP will reflect a 10-year planning horizon. • Link the performance to national goal areas, as appropriate. • Present an analysis of future funding versus condition scenarios. • Illustrate the performance gap between existing conditions and future condition targets. • Estimate the cost of addressing the gap in performance. • Document the process used to conduct the performance gap analysis.
Financial Plan and Investment Strategies	• Summarize historic funding levels for the five assets included in the TAMP. • Describe the amount of funding expected to be available for these assets over the next 10 years and describe where these funds will come from. • Describe how these funds will be allocated over the 10-year horizon. • Document the sources of information used to develop the financial plan. • Document any assumptions made in preparing the financial plan. • Present recommended investment strategies that will enable MnDOT to achieve its performance targets (using information from the previous sections). • Document the process used to evaluate and select investment strategies.
Implementation and Future Developments	• Document a governance plan for the TAMP, including how it will be used and when it will be updated. • Describe priorities for asset management process enhancements and implementation. • Provide plans for expanding the TAMP to include other assets.

MEETINGS AND WORKSHOPS

During the TAMP development process, several face-to-face meetings and facilitated workshops (in addition to numerous teleconference calls) were conducted to review progress, discuss action items and gain feedback from the management team on a wide range of topics. A schedule of these meetings and the key agenda topics are summarized in Figure 1-3.

Figure 1-3: Meetings and Workshops Conducted During the TAMP

DATES	MEETING/WORKSHOP AGENDA TOPICS/DISCUSSION ITEMS
May 29, 2013	Project Kick-Off Meeting: • Establish parameters for developing the TAMP • Develop TAMP Work Plan
June 13, 2013	Steering Committee (SC) Meeting: • TAMP objective and scope • Review work plan and schedule • Role of Steering Committee in TAMP development
July 29-30, 2013	PMT Meeting: • Review content of Asset Register • Discuss objective and plan for the LCC section of the TAMP LCC Workshop: • Review information provided by asset Work Groups on LCC • Discuss LCC modeling strategies for the TAMP
September 20, 2013	Risk Assessment Workshop: • Provide overview on risk management • Discuss and validate undermanaged risks identified • Prioritize undermanaged risks and identify strategies for mitigation
September 26, 2013	PMT Meeting: • Review preliminary life-cycle cost analysis results • Identify next steps in risk assessment • Discuss key information required to develop investment strategies and performance targets
November 14-15, 2013	PMT Meeting: • Discuss preliminary recommendations on investment strategies and performance measures • Discuss recommendations for asset management process improvements SC Meeting: • Discuss strategies to overcome undermanaged risks • Prioritize asset management process improvements • Review and refine recommendations for investment strategies and performance targets
Jan 21-22, 2014	PMT Meeting: • Review and recap completed work activities • Discuss draft TAMP development approach SC Meeting: • Finalize investment strategy recommendations • Recommend business process changes Present recommended investment strategies
Mar 20-21, 2014	PMT Meeting: • Review draft TAMP and gain critical feedback • Discuss plans for development of TAMP Technical Guide • Discuss TAMP governance and application recommendations SC Meeting: • Discuss TAMP governance plan and structure and list of process enhancements that MnDOT will implement • Discuss future activities of the Steering Committee

Supporting Data and Documentation

Figure 1-4 summarizes the MAP-21 requirements and the section of the TAMP that addresses those requirements.

Figure 1-4: Summary of MAP-21 Requirements

MAP-21 REQUIREMENT(S)	SECTION OF TAMP/NOTES
Develop a risk-based asset management plan to improve or preserve asset condition and the performance of the system	Entire document
Include strategies that result in achievement of state targets for asset condition and performance of NHS, and supporting progress towards achievement of national goals	Chapters 2, 3, and 8
States are encouraged to include all infrastructure assets with the right-of-way corridor in the TAMP	Chapter 1 MnDOT expanded beyond MAP-21 requirements to include pavements and bridges on the entire state highway system, as well as highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures
Include a summary listing of pavement and bridge assets on the NHS in the state, including a description of their condition	Chapter 4
Document asset management objectives and measures	Chapters 2, 3
Identify performance gaps	Chapter 7
Include a life-cycle cost analysis for the assets in the TAMP	Chapter 6
Include a risk management analysis	Chapter 5
Include a financial plan and investment strategies	Chapter 8
Document the process used to develop the TAMP	Chapters 1, 2, and 9
Develop a risk-based asset management plan for the NHS to improve or preserve condition of the assets and the performance of the system	Entire document

Chapter 3

ASSET MANAGEMENT PERFORMANCE MEASURES AND TARGETS: SUPPLEMENTAL INFORMATION

ASSET MANAGEMENT PERFORMANCE MEASURES AND TARGETS: SUPPLEMENTAL INFORMATION

Overview

Chapter 3 of the TAMP describes MnDOT's business practices, performance measures, and targets used to monitor and report asset conditions, as well as the new target terminology used in the TAMP. Figure 3-1 summarizes these new key terms associated with targets, which now override the language used to describe performance outcomes in MnSHIP. Moving forward, MnDOT will use the term "target" to denote desired outcomes. The term "plan outcome" will be used to identify outcomes to which MnDOT is managing, while the term "expected outcome" will be used to demonstrate the results of predictive modeling performed using various analytical tools.

Figure 3-1: Summary of New Key Terms Associated with Targets

TERM	MEANING	USE	BASIS FOR ESTABLISHMENT	TERM
Target	Outcome consistent with agency goals and traveler expectations	• Communicate desired outcome • Evaluate performance • Identify investment needs	Approved by senior leadership; guided by agency policies and public planning process	Less than once per planning cycle
Plan Outcome	Outcome consistent with fiscal constraint/spending priorities	• Communicate spending priorities • Develop/manage programs • Select investments	Establish concurrently with the adoption of investment plans	Once per planning cycle
Expected Outcome	Forecasted outcome based on predictive modeling	• Monitor plan implementation • Promote accountability and/or initiate corrective action	Generated by expert offices based on updated performance information and planned improvements	Annually

Chapters 7 and 8 of the TAMP provide a detailed description of the targets, plan outcomes, and expected outcomes for each of the asset classes discussed in the TAMP.

Note:

Chapter 3 of the TAMP contains the majority of needed information pertaining to asset management performance measures and targets. Therefore, no additional information is provided in this chapter of the Technical Guide.

Chapter 4

ASSET INVENTORY AND CONDITIONS: SUPPLEMENTAL INFORMATION

ASSET INVENTORY AND CONDITIONS: SUPPLEMENTAL INFORMATION

Overview

This chapter describes the steps involved in assembling the asset register, which was then converted into a 'folio' for each asset category. The process of finalizing the folios for the TAMP is also described, along with a general procedure to update and maintain the asset register/folios in the future.

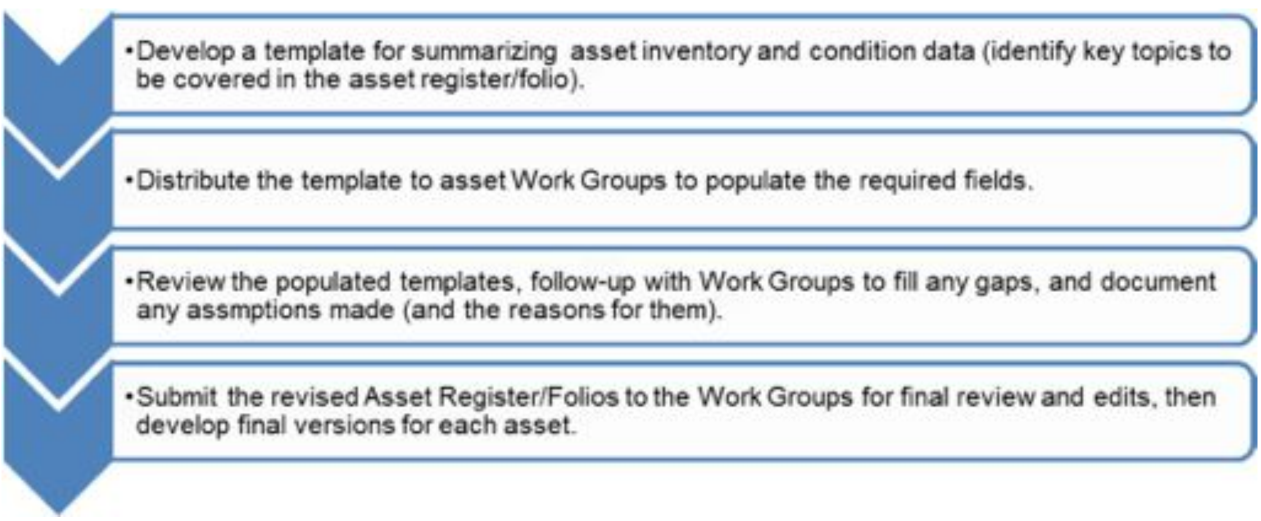
Process

The process of assembling the asset register/folios and the sources of information are presented in this section, and issues related to finalizing the asset register/folios for the TAMP are discussed, along with a simple procedure for maintaining and routinely updating them.

STEPS INVOLVED IN DEVELOPING THE ASSET REGISTER/FOLIOS

The steps involved in developing the asset register/folios are summarized in Figure 4-1.

Figure 4-1: Asset Register/Folios Development Process



KEY INFORMATION SUMMARIZED IN THE ASSET REGISTER/FOLIOS

A typical asset register is divided into six sections. The key information summarized in each section is discussed below. All the information was provided by the asset Work Groups.

ASSET OVERVIEW

This section of the asset register/folio provides a high-level summary of the purpose and importance of the asset and its scope, as covered in the TAMP.

INVENTORY AND REPLACEMENT VALUE

Current asset inventory and replacement value statistics, separated by system or functional classification (if applicable), are summarized in this section.

- **Pavements**: The inventory of flexible (asphalt-surfaced) and rigid (concrete-surfaced) pavements is provided in roadway miles and the total inventory is summarized in both roadway-miles and lane-miles. Replacement value for pavement assets is based on an average replacement cost of $1 million per lane-mile.
- **Bridges**: The bridge inventory is summarized both by count (number of bridges) and by bridge deck area (sq. ft.). Replacement value is computed using a unit cost that ranges from $145 per sq. ft. to $225 per sq. ft., depending on the type of bridge.
- **Hydraulic Infrastructure**: The statewide inventory of highway culverts (count) and deep stormwater tunnels (total length, number of tunnels, and tunnel segments) are summarized. The replacement value for highway culverts was estimated using an average unit cost of $798 per linear ft. (and assuming an average culvert length of 45 ft.), while the replacement value for deep stormwater tunnels was based on the consensus expert opinion of the Work Group.
- **Other Traffic Structures**: The statewide inventory of overhead sign structures and high-mast light tower structures are summarized (a simple count of the structures is used). Replacement values for overhead sign structures and high-mast light tower structures are based on unit costs of $85,000 and $40,000 per structure, respectively.

ASSET AGE PROFILE

This section of the asset register/folio summarizes the age profile (percent of inventory in a given age category) for each asset category included in the TAMP.

DATA COLLECTION, MANAGEMENT, AND REPORTING PRACTICES

The asset data collection protocols and the data management and reporting practices are summarized in this section.

CONDITION RATING SCALE

A graphical representation of the asset condition rating scale used in the TAMP is provided, in order to help compare and contrast the various condition categories used for the different assets.

CONDITION TARGETS AND 10-YEAR INVESTMENT LEVELS

Asset condition (based on the most recent available data), recommended performance targets (discussed in Chapter 3 of the TAMP), and required investment levels to meet those targets (discussed in Chapter 8 of the TAMP) are summarized in this section.

ISSUES IN FINALIZING THE ASSET REGISTER/FOLIOS FOR THE TAMP

Figure 4-2 summarizes the key issues that the project team faced during the development of the asset register/folios – and the strategies adopted to handle them.

Figure 4-2: Information Needed to Develop the TAMP

SECTION	INFORMATION/WORK ACTIVITIES REQUIRED
Too much information covered in asset register, thereby making the format difficult to present in a user-friendly format in the TAMP	In the first version of the asset register, all the assets were included in a single template. To make it more readable, separate folios were created for each asset, rather than forcing a single 'mega-table' for all the TAMP asset categories.
Inconsistencies in data/information from version to version	As the asset register evolved, several inconsistencies were noted in the various versions, primarily because multiple individuals were responsible for updating the data. It was decided that a single person would be responsible for updating the asset register, which resulted in the production of a consistent product (from both content and formatting standpoints).
Uncertainty in data sources and/or assumptions made in arriving at some of the statistics summarized in the asset register	Key assumptions and data sources were summarized as footnotes in the asset register.

PROCESS TO UPDATE AND MAINTAIN THE ASSET REGISTER/FOLIOS

The asset register should be updated on an annual basis; responsibility for delivery of this update should be given to a specific individual at the agency to ensure consistency. The typical process for updating the asset register/folio is summarized below:

- **Step 1**: Provide the most recent version of the asset register/folio to each specific division/department that houses or manages the relevant data. Ask them to review sections 2 through 5 of the asset register/folio (inventory and replacement value; asset age profile; data collection management, and reporting practices; condition rating scale) and provide updates.
- **Step 2**: Update the register/folios based on any new information received and provide a revised copy for final review by the division/department providing the data.
- **Step 3**: Save a final version to the network and make a backup copy.

Chapter 5

RISK MANAGEMENT ANALYSIS: SUPPLEMENTAL INFORMATION

RISK MANAGEMENT ANALYSIS: SUPPLEMENTAL INFORMATION

Overview

This chapter provides a detailed description of the various processes involved in identifying and prioritizing the risks and mitigation strategies described in the TAMP. MnDOT's approach to Enterprise Risk Management is presented in this chapter, along with the steps involved in determining the undermanaged risks presented in the TAMP. The risk management analysis efforts resulted in the production of risk registers specific to each asset category considered in this TAMP. The summarized core content of these risk registers is provided as an attachment at the end of the chapter, along with additional information compiled by each asset Work Group.

Process

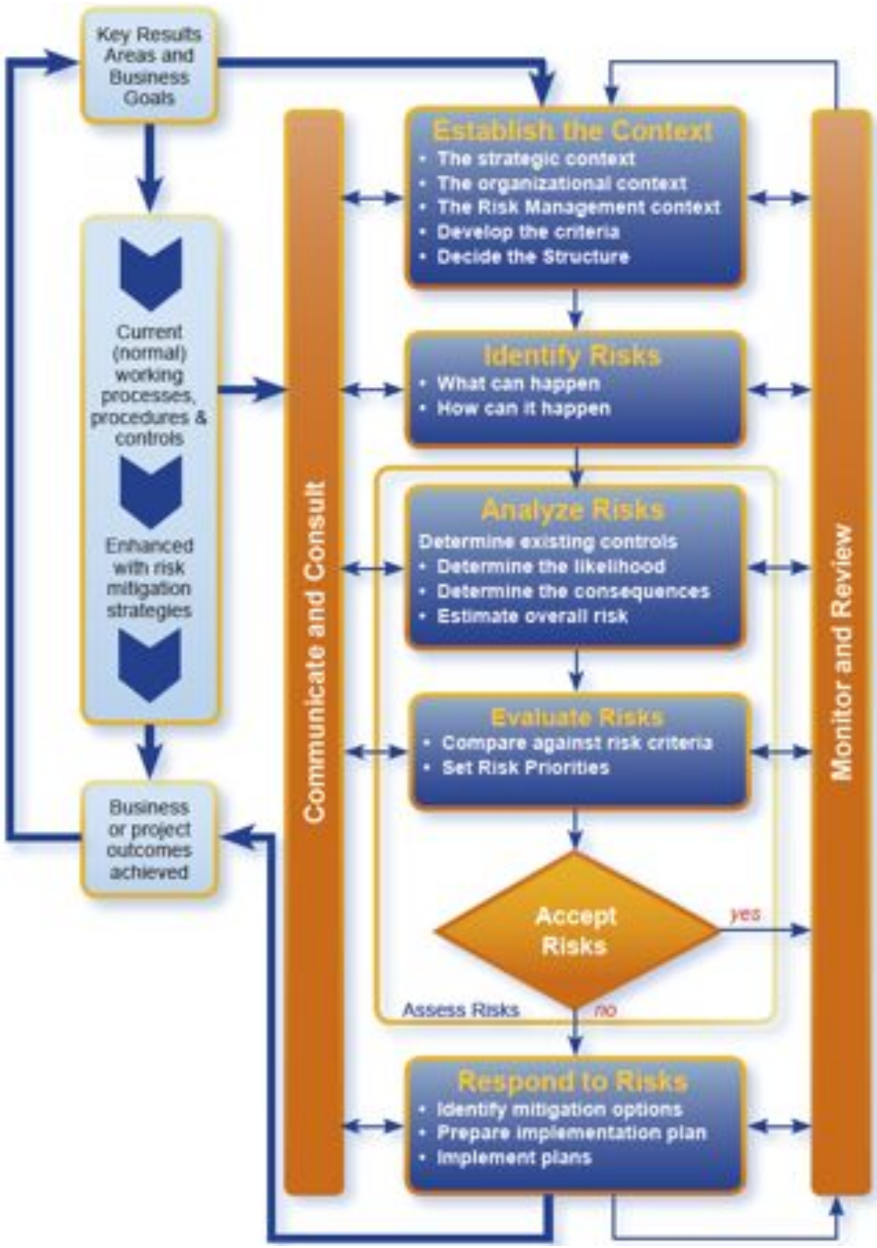
MnDOT's Enterprise Risk Management (ERM) framework – which is used to assess, prioritize, and manage strategic/global risks across the department – is discussed in this section, followed by a discussion of the step-by-step process used in identifying, prioritizing and costing the undermanaged risk opportunities.

ENTERPRISE RISK MANAGEMENT FRAMEWORK

MnDOT has implemented an ERM framework as an integral part of its business processes (illustrated in Figure 5-1[1]). The framework begins with identification of Key Results Areas, which are the MnDOT's priority business and investment objectives. Business planning for these Key Results Areas includes an assessment of strategic risks by senior executives. Business line management groups then assess strategic and business line risks affecting the achievement of their objectives and the delivery of their products and services. At an even more detailed level, project managers identify the risks that threaten project objectives such as scope, schedule, and cost.

Supporting these risk assessment processes, MnDOT maintains a risk register[2], reflecting at any given point in time the current status of strategic and business line risks, including relevant performance measures. The integrated risk register discusses the likelihood and consequences of strategic risks, along with potential

Figure 5-1: MnDOT's Enterprise Risk Management Framework



[1] Source: *MnDOT Enterprise Risk Management Framework and Guidance* (2013).
[2] http://www.dot.state.mn.us/riskmanagement/pdf/july_2013-strategic_risk_register_report.pdf

impacts in the following areas:

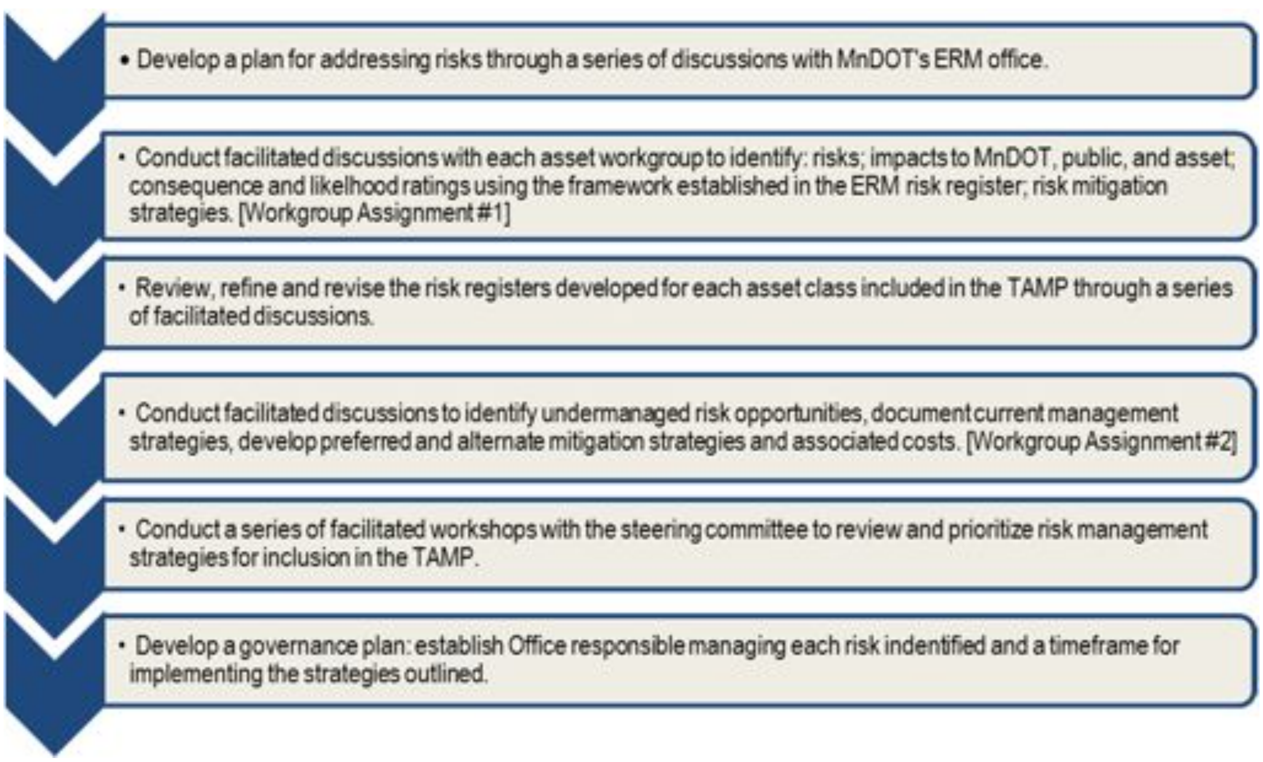
- Agency reputation
- Business performance and capability
- Finance
- Security of assets
- Management effort
- Environment
- Legal and compliance
- Health and safety
- Quality
- Stakeholder engagement

The risk register also provides a risk mitigation plan and a governance structure that indicates the division responsible to manage a particular risk. Since the global/strategic risks (e.g. natural hazards, accidents and crashes, traffic congestion) are already handled effectively through the ERM process, the TAMP focuses on undermanaged risks and opportunities to management/mitigate those risks though process changes and/or capital investments. This procedure is discussed in further detail in the following sections.

RISK MANAGEMENT ANALYSIS PROCEDURE USED IN THE TAMP

The step-by-step approach used in identifying the undermanaged risks is illustrated in Figure 5-2.

Figure 5-2: TAMP Risk Management Analysis Process



WORK GROUP ASSIGNMENT #1: IDENTIFY BROAD RISKS AND IMPACTS (AUGUST/SEPTEMBER 2013)

The first assignment completed by each asset Work Group included the determination of the broad list of risks relevant to each asset class included in the TAMP and the impact of the risk on the asset, the public, and MnDOT. The Work Groups also documented existing control/mitigation strategies being used, gaps in existing business protocols that are preventing MnDOT from managing the risks effectively and the ideal mitigation strategy for the risk identified.

Figure 5-3 summarizes the comprehensive list of risks identified by the asset Work Groups. These lists were discussed among the Work Group participants and those risks that were considered to be undermanaged are shown in italics. The remaining risks (not identified as being undermanaged) are either being addressed through the current management practices and protocols in place for each asset or they are already addressed through the ERM framework (discussed earlier). The undermanaged risks were reviewed in further detail during the development of the strategies for mitigating/managing these risks, identified during the second Work Group assignment. The complete set of documentation developed by the asset Work Groups as a part of the Work Group Assignment #1 is provided as an attachment at the end of this chapter.

Figure 5-3: Risks Identified by Asset Work Groups

PAVEMENTS	**BRIDGES**
• *Not meeting public expectations for pavement quality/condition at the state/district/local levels* • *Inappropriately managing or not managing pavements such as frontage roads, ramps, and auxiliary lanes* • Inability to meet federal requirements (such as MAP-21, GASB, etc.) • Inability to appropriately manage to lowest life-cycle cost • Premature deterioration of pavements • Significant reduction in funding • Occurrence of an unanticipated event such as a natural disaster	• *Lack of or deferred funding* • *Inability to manage to lowest life-cycle cost* • Occurrence of an unanticipated natural event • Catastrophic failure of the asset • Significant damage to the asset through manmade events • *Premature deterioration of the asset* • Shortage of workforce
HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS	**OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES**
• *Failure/collapse of tunnel/culvert* • *Flooding and deterioration due lack of tunnel capacity* • *Lack of culvert capacity* • *Inability to appropriately manage culverts* • Inability to appropriately manage tunnels • Inappropriately distributing funds or inconsistency in culvert investments • Significant damage to culverts through manmade events	• Lack of having a mandated process for inspection • *Poor contract execution* • *Inability to manage to lowest life-cycle cost* • Significant damage to asset through manmade events • Premature deterioration of the asset • Unforeseen changes in regulatory requirements, travel demands, or technology • *Shortage of workforce*

RISK WORKSHOP #1: VALIDATION OF UNDERMANAGED RISKS AND STRATEGY IDENTIFICATION FOR TOP UNDERMANAGED RISKS (SEPTEMBER 2013)

During this workshop, representatives from MnDOT's ERM office provided a brief overview of MnDOT's approach to risk management and how the agency's standardized risk assessment process aligns with the preliminary risks identified by each asset Work Group (shown in Table 5-1). The presentation, which involved members of the Steering Committee as well as Work Group participants, further discussed the proposed plan to focus the TAMP on undermanaged risks. The participants agreed to the approach and participated in a facilitated discussion to identify general mitigation/management strategies for the top undermanaged risks.

Following this workshop, a meeting was held with TAMP Project Management team (on September 26, 2013) to discuss the results of the risk assessment workshop and the next steps. At the conclusion of this meeting, the asset Work Groups, in conjunction with the representatives of MnDOT's ERM office, were tasked with developing comprehensive risk statements that could be used to develop strategies that would help control/mitigate the highest risks. In order to finalize the risk management analysis section of the TAMP, another assignment, which focused on reviewing the undermanaged risks identified in closer detail and developing specific mitigation strategies, was undertaken by the Work Groups (discussed in the next section).

WORK GROUP ASSIGNMENT #2: REVIEW UNDERMANAGED RISKS AND DEVELOP PREFERRED AND ALTERNATE MITIGATION STRATEGIES (OCTOBER/NOVEMBER 2013)

The second assignment completed by the asset Work Groups built on the previous information but specifically focused on the undermanaged risks. The step-by-step procedure followed by the Work Groups to complete this assignment is summarized below:

- **Step 1**: Define preferred mitigation strategy for addressing the risk identified.
- **Step 2**: Identify data, resources, tools, and/or training required to enact the strategy.
- **Step 3**: Describe whether the strategy will reduce the likelihood of another identified risk.
- **Step 4**: Estimate the approximate cost of implementing the preferred mitigation strategy.
- **Step 5**: Identify whether an alternate strategy might be available that doesn't fully mitigate the risk but lowers the overall likelihood or consequence associated with the risk.
- **Step 6**: Estimate the cost associated with the alternate strategy.
- **Step 7**: For both strategies developed, identify the impact on likelihood and consequence of the original risk should either of the strategies be adopted.

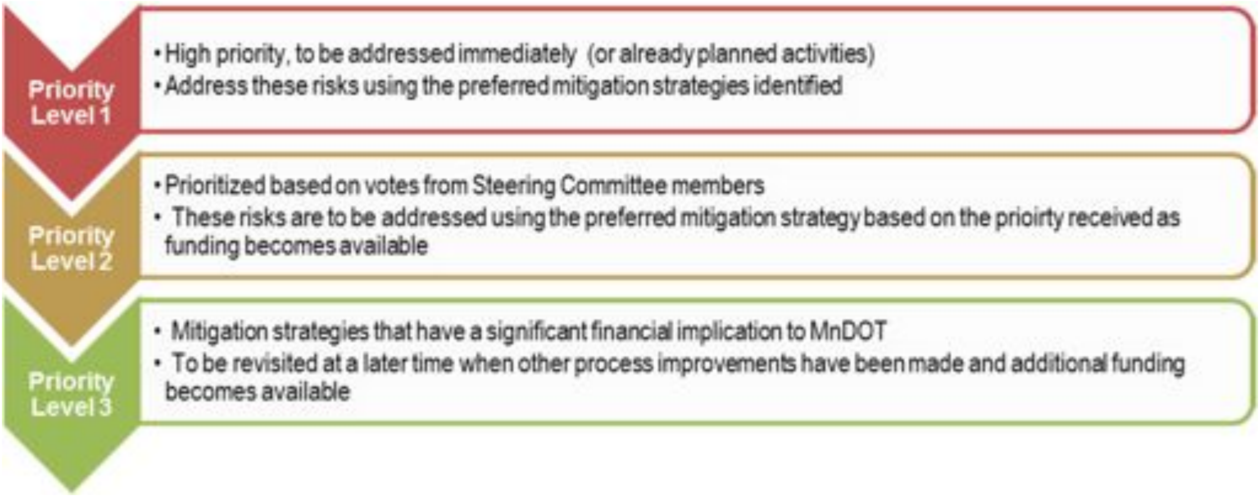
A detailed version of the guidance provided to the Work Groups on Assignment #2 and the results are provided as attachments at the end of this chapter.

RISK WORKSHOP #2: PRIORITIZATION OF RISK MITIGATION STRATEGIES (NOVEMBER 2013)

The undermanaged risks developed by the Work Groups were organized into one of two broad categories: "Capital Investments" or "Process Improvements". Those risks that were considered to be process improvements were ranked by the workshop participants. Strategies that involved capital investments were not included in the prioritization process because those risks would likely be addressed elsewhere within MnDOT. Also, process improvement initiatives that were considered to be very low-cost activities that provided a high return on investment were excluded from the prioritization process because they were clearly high priorities and most of them were already underway. Based on votes from the Steering Committee members, the risk mitigation strategies associated with bridge process improvements received the highest priority, followed by process improvements for highway culverts, deep stormwater tunnels, pavements, and overhead sign structures / high-mast light tower structures.

The results of the Risk Workshop #2 were then used to develop final priorities for the TAMP using the general process summarized in Figure 5-4. (Results of this process are summarized in Figure 5-7 of the main TAMP document).

Figure 5-4: Prioritization Strategy for Risks to be Managed by MnDOT



Supporting Data and Documentation

As discussed in the previous sections, a number of documents were prepared as part of the risk management analysis efforts undertaken by the asset Work Groups. These include:

- Results of Work Group Assignment #1: Identify Broad Risks and Impacts
- Results of Work Group Assignment #2: Review Undermanaged Risks and Develop Preferred and Alternate Mitigation Strategies and Costs

The key findings related to the undermanaged risks (from Work Group Assignments #1 and #2) are summarized in this section, and detailed worksheets prepared by the Work Groups as supporting documentation and detailed instructions are provided at the end of the chapter.

SUMMARY OF FINDINGS FROM THE RISK MANAGEMENT ANALYSIS WORK GROUP EFFORTS

The Work Group process was iterative and extended over two formal workshops, with opportunities between workshops to modify certain aspects of the product. Participants took advantage of the process to learn about the risks, assess the ability of existing information systems to quantify risks and costs, and reach consensus on priorities and approaches for future improvements. Undermanaged risks identified in the TAMP are summarized in the following sections.

PAVEMENTS

The Pavements Work Group developed two risk statements and a set of mitigation strategies and risk ratings for each of them. Figure 5-5 summarizes the risk management analysis performed by the Work Group.

Figure 5-5: Pavement Risk Management Analysis Summary

Risk Statement (#1) Mitigation Strategies, Impacts on Other Risks, and Costs

Risk Statement #1:

Non-Attainment of Objectives: If public expectations for pavement quality or condition are not met, especially at the local/corridor level, then the agency's reputation may suffer, service delays and unsafe conditions may increase and the cost of maintenance may grow.

- Current control/mitigation strategies: Using money to manage to lowest life-cycle cost including routine maintenance; money distributed statewide based on need; implementation of performance measures and targets; balanced funding across entire system; MAP-21 direction to allocate funding to the National Highway System; staging of more timely and appropriate treatments; and multiple fixes at each location or on each corridor.
- Previously identified mitigation strategies: More timely and appropriate staging of treatments; multiple fixes at location or on corridor (only if LCC treatment intervals modified); more systematic and standardized statewide approach to fixes.

Preferred Mitigation Strategy, Resources, and Costs:

Annually track, monitor and identify roadway segments that have been in Poor condition greater than five years, and consistently consider this information when programming at the district level. The cost would be eight hours of staff time to run a report and coordinate with districts during annual programming activities. (*Process Improvement Strategy*)

Effect on Other Risks: May reduce the risk of failing to comply with GASB Statement 34 requirements.

Alternate Mitigation Strategy and Costs:

Jurisdictional realignments, to divest maintenance responsibility onto other agencies. Divestiture could cost $200,000 per mile to bring roads up to a standard necessary for acceptance by another agency. An outreach plan and communication strategy – at a possible cost of $25,000 – may reduce the potential loss of reputation if the MnDOT fails to meet objectives.

Likelihood and Consequence of Adverse Impacts

	Consequence	Likelihood	Risk Rating
Original Risk Rating	Major	Likely	High
Preferred Strategy	Major	Possible	Medium
Alternate Strategy	Moderate	Likely	Medium

Risk Statement (#2), Mitigation Strategies, Impacts on Other Risks, and Costs

Risk Statement #2:

Exclusion of Auxiliary Roads: If MnDOT does not include ramps, access roads, auxiliary lanes and frontage roads in its pavement inventory and use their condition in its pavement model, then these assets will not be included in pavement management decisions and cannot be managed to achieve the lowest life-cycle cost for all highway pavements.

- Current control/mitigation strategies: None.
- Previously identified mitigation strategies: Increased indefinite-quantity or blanket-type projects to address localized distresses, with better tracking of deterioration and condition.

Preferred Mitigation Strategy, Resources, and Costs:

1. Collect additional data in the Metro District with the use of the old Material Office pavement van, at an estimated cost of $100 per mile. (*Process Improvement Strategy*)
2. Build a stand-alone database that will house pavement data and allow for better tracking, with a cost range of $2,000 to $20,000. (*Process Improvement Strategy*)

Alternate Mitigation Strategy and Costs:

Collect data in Greater Minnesota districts by hand, using maintenance staff. Visually collect images through video capture or windshield survey. These would cost around $100/mile to collect data and additional cost/time to enter information into the database.

Likelihood and Consequence of Adverse Impacts

	Consequence	Likelihood	Risk Rating
Original Risk Rating	Minor	Possible	Low
Preferred Strategy	Minor	Unlikely	Low
Alternate Strategy	Minor	Unlikely	Low

BRIDGES

Figure 5-6 summarizes the bridge risk management analysis performed by the Bridge Work Group. The Work Group developed two risk statements, an integrated set of mitigation strategies, and associated risk ratings.

Figure 5-6: Bridge Risk Management Analysis Summary

Risk Statements (#1 & #2) Mitigation Strategies, Impacts on Other Risks, and Costs
Risk Statement #1: **Life-Cycle Cost**: If bridge inspection data, bridge model sophistication, and bridge deterioration models are not accurate or complete, then it may be difficult to determine the lowest life-cycle cost strategy for bridges. • Current control/mitigation strategies: BRIM (Bridge Replacement and Improvement Management) system; SIMS (Structure Information Management System); performance measures. • Previously identified mitigation strategies: Link BRIM, SIMS, Swift (MnDOT financial management system), contract preservation costs and AASHTOWare Bridge Management 5.2 (bridge management system) in order to make appropriate management decisions; develop a preventive maintenance performance measure; improve knowledge of deterioration curves.
Risk Statement #2: **Premature Deterioration**: If one or more bridges deteriorate prematurely, then maintenance costs may be higher than expected and there may be unanticipated risks to structural integrity. • Current control/mitigation strategies: Inspection and maintenance tracking to try to anticipate needs; ability to track and prioritize work. • Previously identified mitigation strategies: Better inspection and maintenance tracking; better knowledge of deterioration curves; implementation of the AASHTOWare Bridge Management 5.2 system.
Preferred Mitigation Strategy, Resources, and Costs (Process Improvement Strategy: 1. Finish development of SIMS Maintenance Module. • This system is currently in development. MnDOT has in-depth maintenance data back to 2009 which needs to be migrated into the SIMS Maintenance Module. • Requires 50 Trainees and 2 instructors for eight 4-hour training sessions located around the state, plus curriculum development and data migration. The total effort is about 400 hours. 2. Develop the Preventive Maintenance (PM) Program, including a performance measure to verify that PM is performed at the right time. This will require collaboration with MnDOT districts, including annual meetings. 3. Develop a Business Intelligence reporting tool to link SIMS and Swift. • This is currently in the data discovery phase, and no cost estimate has yet been prepared. • Training for three power users with one instructor for two full-day sessions would total 64 hours. Training for 29 regular users with one instructor for one full-day session would total 240 hours. 4. Migrate inspection and maintenance data to AASHTOWare Bridge Management 5.2 (when completed), create and utilize the deterioration curves. As part of this step, existing bridge element condition data will need to be converted according to upcoming Federal requirements and AASHTO specifications. • Multi-state collaboration for AASHTOWare development costs $50,000 per year for five years (29 states are participating). • MnDOT will need resources and equipment to test and implement the BrM 5.2 system. MnDOT will need to develop deterioration curves and cost models from Minnesota data. 5. Link Construction Costs with Maintenance costs in the new Business Intelligence reporting tool. 6. Link BRIM and AASHTOWare BrM 5.2, which will allow future bridge data and models to participate in the BRIM risk analysis. 7. Compare cost, age, and performance trends of the bridge system to determine effectiveness of management strategy, and adjust accordingly. 8. Research to further identify lowest life-cycle cost (e.g. deterioration models, effectiveness of maintenance activities, products, etc.) • Deck deterioration and National Bridge Element research is currently in progress. • Other research may be needed.

Approximate Cost of Preferred Mitigation Strategy: **$2 million.** This represents a one-time implementation cost. Following implementation, this will be a low-cost strategy to maintain annually.
Effect on Other Risks: The preferred strategy will mitigate both of the risks identified in this exercise (manage to lowest life-cycle cost and premature deterioration) as well as help to mitigate the lack or deferral of funding.
Alternate Mitigation Strategy and Costs: 1. Finish development of SIMS Maintenance Module (already in progress). 2. Develop the Preventive Maintenance (PM) program and performance measure (in progress) to verify that PM is performed at the right time. 3. Cost accounting tracking through existing systems (WOM, Financial Reports). These systems are not tied with maintenance data in SIMS. 4. Migrate inspection and maintenance data to AASHTOWare BrM 5.2 (when completed) and create/utilize the deterioration curves. As part of this step, existing bridge element condition data will need to be converted according to upcoming Federal requirements and AASHTO specifications. Under this alternate strategy, the Business Intelligence reporting tool would not be used and BRIM would not be linked to future bridge inspection data. **Approximate Cost of Alternate Mitigation Strategy:** **$1.4 million.** This represents a one-time implementation cost. Following implementation, this will be a low-cost strategy to maintain annually.

Likelihood and Consequence of Adverse Impacts

	Consequence	Likelihood	Risk Rating
Original Risk Rating	Moderate	Likely	Medium
Preferred Strategy	Minor	Likely	Medium
Alternate Strategy	Moderate	Likely	Medium

HIGHWAY CULVERTS

Figure 5-7 summarizes the highway culvert risk management analysis performed by the Hydraulics Work Group.

Figure 5-7: Highway Culvert Risk Management Analysis Summary

Risk Statement, Mitigation Strategies, Impacts on Other Risks, and Costs
Risk Statement: **Inability to manage culverts**: If highway culverts are not managed effectively, then the risk of failure and the life-cycle cost of ownership may increase. • Current control/mitigation strategies: MnDOT (partially) inventories and inspects highway culverts and the information is used to plan maintenance work and project scoping activities. Highway culvert failures are repaired when they occur. • Previously identified mitigation strategies: Additional funding to be able to implement a systematic management approach based on targeted work, complete life-cycle cost understanding, data provided, shared and used by design, construction, maintenance.

Preferred Mitigation Strategy, Resources, and Costs:
1. Adopt a system condition performance measure, and set performance targets. This will need about 200 hours of staff time. (*Process Improvement Strategy*)
2. Implement the proposed Asset Management System and gather data that will support life-cycle cost analysis (*Process Improvement Strategy*). This will require:
  • Funds to purchase and implement Transportation Asset Management System – at least $1 million and 1000 hours of staff time.
  • Staff and consultant resources to develop business rules – roughly $50,000 in costs and 500 hours of staff time.
  • Staff and consultant resources to collect data for the asset management system. This is estimated to require 16,000 hours per year.
3. Repair or replace highway culverts in accordance with Asset Management System recommendations through capital

projects and maintenance work. This is estimated to require $40 million per year. (*Capital Investment Strategy*)
Effect on Other Risks: The preferred strategy will reduce the likelihood of road failure, interruption of service, lack of adequate capacity, and land owner drainage complaints. The strategy will also reduce the risk of not being able to support the HydInfra information system currently used for culvert data.
Alternate Mitigation Strategy and Costs: Stand-alone construction projects to repair or replace Poor and Very Poor highway culverts. This would entail $1.25 million to implement the Transportation Asset Management System (does not include life-cycle cost functionality) and 800 staff hours. The cost to repair or replace culverts would need to be significantly more than the current $30 million per year and likely more than the $40 million in the preferred strategy, to clear the existing backlog and stabilize future performance.

Likelihood and Consequence of Adverse Impacts

	Consequence	Likelihood	Risk Rating
Original Risk Rating	Moderate	Almost Certain	High
Preferred Strategy	Moderate	Possible	Medium
Alternate Strategy	Moderate	Likely	Medium

DEEP STORMWATER TUNNELS

The Hydraulics Work Group developed two deep stormwater tunnel risk statements and a set of mitigation strategies and risk ratings for each. Figure 5-8 summarizes the risk management analysis performed by the Work Group.

Figure 5-8: Deep Stormwater Tunnel Risk Management Analysis Summary

Risk Statement (#1) Mitigation Strategies, Impacts on Other Risks, and Costs

Risk Statement #1:

Capacity: If stormwater tunnel capacity is not adequate for a major rain event and resulting pressurization is too great, then the tunnel will be damaged or collapse, local flooding may occur, property may be damaged, and people may be killed or injured.

- Current control/mitigation strategies: None.
- Previously identified mitigation strategies: Provide a new tunnel system and back charge City of Minneapolis; City to separate its water (as much as possible); downsize new/modified system as much as possible to save costs

Preferred Mitigation Strategy, Resources, and Costs:

1. Complete research on underground storage options, including the exploration of shallow cavern storage options for South (I-35W) tunnel. The estimated cost is $30,000. Then build the I-35W South underground storage cavern, at a cost of $50 million. (*Process Improvement Strategy*)
2. Develop and implement emergency response plan for business, residential, and freeway areas along the flood-prone I-35W South tunnel. The estimated cost is $15,000. (*Process Improvement Strategy*)

Effect on Other Risks: May reduce the risk of failing to comply with GASB Statement 34 requirements.

Alternate Mitigation Strategy and Costs:

Build the I-35W South underground storage cavern, at a cost of $50 million.

Likelihood and Consequence of Adverse Impacts

	Consequence	Likelihood	Risk Rating
Original Risk Rating	Catastrophic	Likely	Extreme
Preferred Strategy	Catastrophic	Rare	High
Alternate Strategy	Catastrophic	Rare	High

Risk Statement (#2), Mitigation Strategies, Impacts on Other Risks, and Costs

Risk Statement #2:

Disrepair: If the needed maintenance repairs are not made in a timely manner, then tunnels may collapse in a major rain event, and significant property damage, loss of life, or extensive service disruption may occur and significant reconstruction costs may be necessary.

- Current control/mitigation strategies: Tunnels, with the exception of one, have been thoroughly inspected once to gauge baseline condition. Repairs have been prioritized.
- Previously identified mitigation strategies: MnDOT and communities prioritize construction funding. Establish detour routes

in advance; map extent of possible flooding; increase funding for rehabilitation, perform data collection and inspection to determine life-cycle costs and deterioration rates; work with Cities to redefine management of tunnels to more of a coordinated effort.
Preferred Mitigation Strategy, Resources, and Costs: 1. Inspect the one remaining uninspected tunnel at a cost of $50,000. (*Process Improvement Strategy*) 2. Install pressure transducers in tunnels to measure pressurization. Cost undetermined. (*Process Improvement Strategy*) 3. Design and implement a mandated inspection frequency (1-5 years) based on tunnel/segment condition rating, at an average cost of $250,000 per inspection. (*Process Improvement Strategy*) 4. Include tunnels in the bridge inventory. This will require cooperative work with district offices and the Central Office bridge group, and may require consultant assistance. (*Process Improvement Strategy*) 5. Prepare plans and implement all repairs needed on the South I-35W tunnel system at MnDOT cost, with City of Minneapolis funding used for all other known repairs on all other tunnels. This may require transportation bond financing of $12 million, which has already been allocated by MnDOT. (*Capital Investment Strategy*)
Effect on Other Risks: This work will improve MnDOT credibility in the event of a failure. It will strategically fix the worst tunnel repair needs. It may reduce the likelihood of failure by having increased information on tunnel condition – as long as funding is available for repairs when conditions warrant it.
Alternate Mitigation Strategy and Costs: 1. Staff from MnDOT (likely Metro Bridge Maintenance), trained on inspections, complete them on select tunnel segments after major rain events. 2. MnDOT hires a consultant to complete inspections on each tunnel, as identified by mandated inspection guidelines. 3. Begin repairs incrementally and withhold funding to cities on other projects if proposed repair schedules are not met. This is estimated to cost an average of $3.5 million per segment.

Likelihood and Consequence of Adverse Impacts

	Consequence	Likelihood	Risk Rating
Original Risk Rating	Catastrophic	Possible	High
Preferred Strategy	Catastrophic	Possible	High
Alternate Strategy	Catastrophic	Rare	Medium

OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES

The Overhead Sign Structures / High-Mast Light Tower Structures Work Group developed three risk statements and a set of correlating mitigation strategies. Figure 5-9 summarizes the risk management analysis performed by the Work Group.

Figure 5-9: Overhead Sign Structures and High-Mast Light Tower Structures Risk Management Analysis Summary

Risk Statement (#1) Mitigation Strategies, Impacts on Other Risks, and Costs
Risk Statement #1: **Construction Defects**: If overhead sign structures and high-mast light tower structures are not properly installed as part of a construction project, then they may deteriorate more rapidly, requiring more subsequent maintenance. • Current control/mitigation strategies: None. • Previously identified mitigation strategies: Better quality controls (e.g. MnDOT inspections) of construction work outside of edge-of-pavement-to-edge-of-pavement; better checklist to include roadside infrastructure; routine/mandatory workshops at end of each construction project.
Preferred Mitigation Strategy, Resources, and Costs: 1. Change construction specifications to require torque threshold dye washers. This would entail a one-time investment of 40 hours of staff time, and an increased annual cost of $20,000 per year. (*Process Improvement Strategy*) 2. Communicate punch list and specifications with companies that install structures and with construction inspectors. This might increase staff time requirements by 200 hours per year. (*Process Improvement Strategy*)
Effect on Other Risks: Reducing the risk of poor contract execution should extend the life of the structure and reduce maintenance costs, thus reducing life-cycle costs.
Alternate Mitigation Strategy and Costs: MnDOT Maintenance will tighten the nuts on all new structures. A one-time cost of $40,000 would be needed to purchase additional machinery necessary to secure the structures, plus an increased annual cost of $2,000 for additional staff and equipment.

Likelihood and Consequence of Adverse Impacts			
Likelihood and Consequence of Adverse Impacts			
	Consequence	**Likelihood**	**Risk Rating**
Original Risk Rating	Minor	Likely	Medium
Preferred Strategy	Minor	Rare	Low
Alternate Strategy	Minor	Rare	Low

Risk Statement (#2) Mitigation Strategies, Impacts on Other Risks, and Costs

Risk Statement #2:

Life-Cycle Cost: If overhead sign structure and high-mast light tower structure inspection data and deterioration models are not accurate or complete, then it may be difficult to determine the lowest life-cycle cost for these assets.

- Current control/mitigation strategies: Bridge Office Structural Metals and Bridge Inspection Engineer notify Electrical Services after pole is inspected as to what repairs are required for each pole.
- Previously identified mitigation strategies: Develop an enterprise asset management system for better tracking of asset status and better assignment of responsibility for condition and work accomplishment information.

Preferred Mitigation Strategy, Resources, and Costs:

1. Adopt a MnDOT policy/technical memo requiring a five-year inspection frequency for all overhead structures (approx. 40 staff hours). (*Process Improvement Strategy*)
2. Report annually on inspection frequency results (approx. 40 hours per year). (*Process Improvement Strategy*)
3. Create a training program for inspecting and maintaining structures, develop inspection forms, develop clear condition rating criteria. This would require a one-time cost of 320 hours, plus about 80 hours per year. (*Process Improvement Strategy*)
4. Gain efficiencies by using mobile technology in the field, at a cost of about $10,000 per year. (*Process Improvement Strategy*)

Alternate Mitigation Strategy and Costs:

Use consultants to perform the work, and/or increase inspection intervals. An average of $800 per structure was previously paid for external inspection. Internal inspections cost roughly $100 per structure.

Likelihood and Consequence of Adverse Impacts			
	Consequence	**Likelihood**	**Risk Rating**
Original Risk Rating	Minor	Likely	Medium
Preferred Strategy	Minor	Rare	Low
Alternate Strategy	Minor	Likely	Medium

Risk Statement (#3), Mitigation Strategies, Impacts on Other Risks, and Costs

Risk Statement #3:

Labor Shortage: If MnDOT is unable to provide a sufficient number of workers to maintain high-mast light tower structures or overhead sign structures, then inspections, maintenance, repairs and replacement may fall short of service standards.

- Current control/mitigation strategies: None.
- Determine risk to public if MnDOT staff is decreased; cross training of staff (redundancy in knowledge).

Preferred Mitigation Strategy, Resources, and Costs:

1. Implement the proposed Transportation Asset Management System to include a work order, resource, and materials cost tracking module. This would entail a one-time cost of $250,000 and annual costs of $100,000 for software maintenance and usage costs. (*Process Improvement Strategy*)
2. Report annually on life-cycle cost and identify and implement refined/additional strategies to reduce costs, at a cost of 80 staff hours per year. (*Process Improvement Strategy*)

Alternate Mitigation Strategy and Costs:

1. Maintain status quo with replacement cycle of 40-50 years.
2. When an overhead sign structure or high-mast light tower structure are due for replacement, remove and replace with 6-8 standard lights or ground mount overhead.
3. Conduct research that will better define/determine deterioration rates and collect additional information.

Likelihood and Consequence of Adverse Impacts			
	Consequence	**Likelihood**	**Risk Rating**
Original Risk Rating	Minor	Possible	Low
Preferred Strategy	Minor	Rare	Low
Alternate Strategy	Minor	Rare	Low

Work Group Assignment #1: Identification of Pavement Risks (including undermanaged)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	
				Has MnDOT been managing this risk effectively?			What is the risk rating?			
					If No:					
Risks:	**Impact of not managing the risk effectively to: (you do not have to have impacts in all three areas for each risk)**			**If Yes, List control/mitigation strategies used**	**List gaps in current business protocols preventing MnDOT from managing the risk effectively**	**Ideal Mitigation Strategy(ies)**	**Consequence of Risk Occurring**	**Likelihood of Risk Occurring**	**Overall Risk Rating**	**Most Undermanaged Risk**
	Asset	**Public**	**MnDOT**							
Not Meeting Public Expectations for Pavement Quality/Condition	Strain on Rest of System; Economy; Lower Quality of Life; Traveler Safety; Higher Maintenance Costs	Economy (commodities); Lower Quality of Life; Traveler Safety; Service Delays for Traveling Public;	Reputation Higher Maintenance Cost, and other asset maintenance is deferred.	Using money to manage to lowest lifecycle cost including routine maintenance; money distributed statewide based on need, measures & targets; balanced across entire system; MAP-21 direction (allocates $ on NHS); staging of treatments (more timely & appropriate treatments); multiple fixes at location or on corridor		Staging of treatments (more timely & appropriate treatments); multiple fixes at location or on corridor (IF LCC TREATMENT INTERVALS MODIFIED)	Moderate	Possible	Low	x
Statewide							Moderate	Possible	Low	
District Level						Small portion of DRMP is condition based	Moderate	Likely	Medium	
Local Level - Corridor (predicted or premature)						Manage expectations	Major	Likely	High	
Inappropriately Managing or Not Managing Pavements Such as Frontage Roads, Ramps, Auxiliary Lanes, etc.						Increased IDIQ or BARC type projects to address localized distresses	Minor	Possible	Low	x
Federal MAP-21 and GASB Requirements	Shorter/Wrong Fixes (e.g. Medium Mill & Overlay vs. Major Rehab./Construction)	Traveler Safety	Federal Funds withheld, bond rating impacted.	Same as above	Funding assigned to pavement has been too low, leading to low RQI, now it's difficult to catch up.	Provide funding to actually exceed targets, so that we could endure occasional budget shortfalls.	Major	Rare	Low	
Inability to Appropriately Manage Lowest LCC for Pavements	Project Deferrals/Delays or Shorter Term Fixes; Increased Operations Costs. Construction costs go up as conditions worsen. Missing Data and/or Hidden Costs (scope creep)	More Poor Roads; Traveler Safety. More auto repairs, more money spent on gas, risk of tax increases.	Additional Strain on MnDOT Maint./Operations Staff; Additional Funding Needed for Fixes	Same as above		Consistency on types of fixes statewide; managed system-wide (balance between project, district or statewide LCC - all three different); better coordination across offices and jurisdictions (e.g. pavement, safety, bridge, hydraulics, etc.) - think all inclusive corridor investments. Inventory and include all pavement in Pavement Management System.	Moderate	Possible	Medium	
Premature Deterioration of Pavements	Project Deferrals/Delays or Shorter Term Fixes; Increased Operations Costs	More Poor Roads; Traveler Safety	Additional Strain on MnDOT Maint./Operations Staff	Same as above		District Risk Management Program (DRMP) changes to align with shifts in pavement condition; Begin to document	Moderate	Possible	Medium	
Funding Being A Lot Less than Expected	More Poor Roads	More Poor Roads; Traveler Safety	Reputation	Same as above		Invest only in roads with ADT above a certain number (e.g. 2000 ADT)	Minor	Possible	Low	
Occurrence of an unanticipated event, natural disaster	Assets unusable	Service Delays, Traveler safety	Additional funding needed for fixes			Invest network-wide when unforeseen costs occur, stretch funding	Major	Rare	low	

Work Group Assignment #1: Identification of Bridge Risks (including undermanaged)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10			
				Has MnDOT been managing this risk effectively?			What is the risk rating?				Most Undermanaged Risks	
					If No:							
Risk of:	**Impact of not managing the risk effectively to: (you do not have to have impacts in all three areas for each risk)**			**If Yes, List control/mitigation strategies used**	**List gaps in current business protocols preventing MnDOT from managing the risk effectively**	**Ideal Mitigation Strategy**	**Consequence of Risk Occurring**	**Likelihood of Risk Occurring**	**Overall Risk Rating**	**Discussion Comments**		**Validation**
	Asset	**Public**	**MnDOT**									
Lack of or deferred funding (e.g., unexpected budget cuts)	Highest needs first; more reactive maintenance; low cost preservation to limp assets along; more frequent inspections	Potential for unsafe driving conditions; increased service interruptions; decreased public confidence; bridge or route restrictions	Do not meet performance targets; defer non-critical repairs; unmanageable growth of bridge needs; increased operations resource needs	BRIM (Bridge Replacement and Improvement Management); SIMS (Structure Information Management System)	SIMS Maintenance Module (in progress); linking costs to maintenance tasks (Swift, SIMS and BI); SIMS, BRIM and construction cost data not linked; implementation and use of a multi-objective optimization tool in BrM 5.2 (in development)	Link BRIM, SIMS, Swift, contract preservation costs and BrM 5.2 in order to make appropriate management decisions	Moderate	Possible	Medium	Does the likelihood of this risk concur with OCPPM?	x	The management programs (and links between the management programs) are not in place to be able to manage from an "entire system" asset management and life cycle cost approach.
Inability to manage to lowest life-cycle cost (e.g., preventive activities not performed on a timely basis)	Deteriorates faster (reduced bridge service life); more reactive maintenance; higher life cycle cost; manage highest needs first	Increased duration and frequency of service interruptions; decreased public confidence; bridge or route restrictions	More bridges falling into lower service conditions faster; do not meet performance targets; increased operations resource needs	BRIM; SIMS; Performance Measures	SIMS Maintenance Module (in progress); linking costs to maintenance tasks (Swift, SIMS and BI); SIMS, BRIM and construction cost data not linked; Preventive Maintenance Performance Measure still in development; Deterioration Curves; implementation and use of the multi-objective optimization tool in BrM 5.2 (in development)	Link BRIM, SIMS, Swift, contract preservation costs and BrM 5.2 in order to make appropriate management decisions; Preventive Maintenance Performance Measure; Deterioration Curves	Minor to Moderate	Likely	Medium	We could have a >$5M risk potential.	x	The management programs (and links between the management programs) are not in place to be able to manage from an "entire system" asset management and life cycle cost approach.
Occurrence of an unanticipated natural event (e.g. flood, earthquake, adverse weather)	Unexpected need - more resources assigned to that asset; scheduled bridge investments are deferred	Safety; increased service interruptions; detours; congestion	Changed maintenance program: top needs are redefined; unanticipated resources assigned to a single asset and other priorities are deferred	Design preventive measures; regular scour monitoring for scour critical bridges; debris removal; having resources available to react; ability to track and prioritize work	Maintenance resource and scheduling still in development (SIMS Maintenance Module); Up to date emergency response plan or critical infrastructure plan	Preventive Measures; Emergency Response Plan; Resource and Scheduling to reallocate resources	Major Moderate Minor	Rare to Unlikely Possible Likely	Low to Medium Medium Medium	Is this a major event? Are we looking at this from a statewide perspective or a local perspective? This could have three different answers for consequence and likelihood depending on the severity of the event and the perspective.		
Catastrophic failure of the asset (e.g., unexpected bridge collapse)	Unexpected need - more resources assigned to that asset; scheduled bridge investments are deferred	Safety; increased service interruptions; detours; congestion; decreased public confidence	Changed maintenance program: top needs are redefined; unanticipated resources assigned to a single asset and other priorities are deferred; management strategy and policies are investigated and redefined	Inspection frequency and best practices; performing required maintenance; having resources available to react; designing resilient bridges	Comprehensive Inspection Manual (in progress); Up to date emergency response plan or critical infrastructure plan	Inspection and Maintenance; Emergency Response Plan	Catastrophic	Rare	Medium			
Significant damage to the asset through man made events (e.g., crashes, damage from construction activities etc.)	Unexpected need - more resources assigned to that asset; scheduled bridge investments are deferred	Safety; increased service interruptions; detours; congestion	Changed maintenance program: top needs are redefined; unanticipated resources assigned to a single asset and other priorities are deferred	Having resources available to react; ability to track and prioritize work; inspection, permitting and restitution processes; preventive measures; designing resilient bridges	Up to date emergency response plan for at risk bridges; Maintenance resource and scheduling still in development (SIMS Maintenance Module); Restitution tracking; Linking Costs to Maintenance Tasks	Preventive Measures; Emergency Response Plan; Resource and Scheduling to reallocate resources; Inspection; Permitting process; Restitution	Major	Unlikely	Medium	Are we only looking at significant damage? Bridge hits and accidents happen more often than "unlikely" represents, but they do not all result in "significant" damage. What percentage of the bridge system is actually affected? This may be more of a localized risk.		
Premature deterioration of the asset (e.g., service lives 10 to 20 percent shorter than expected)	Unanticipated reactive maintenance or major investments required sooner; reduced service life	Increased duration and frequency of service interruptions; bridge or route restrictions; safety; decreased public confidence	Do not meet performance targets; changed maintenance program; increased operations resource needs	Inspection and maintenance tracking to try to anticipate needs; ability to track and prioritize work	SIMS Maintenance Module (in progress); Deterioration curves; implementation and use of the multi-objective optimization tool in BrM 5.2 (in development)	Inspection and Maintenance tracking; Deterioration curves; BrM 5.2	Moderate to Major	Unlikely	Medium	Is this from a "whole system" perspective or from an individual bridge perspective? This will affect the consequence and likelihood values.	x	The management programs (and links between the management programs) are not in place to be able to manage from an "entire system" asset management and life cycle cost approach. Need improved deterioration models for our bridges.
Shortage of workforce (e.g., early retirements and hiring freezes)	Maintenance not performed when needed; impacts to design, scoping, estimates, load rating, data management, etc.	Decreased public confidence; increased service interruptions	Not enough resources to perform the work and lack of knowledgeable and experienced workers to perform the work efficiently and effectively.	Bridge training program; Bridge Maintenance Academy training; technology; Consultant Contracts	Performance and Efficiency Measures for performing all tasks (design, load rating, scoping, estimates, inspection and actual maintenance on the structure) as well as the link between the measures	Training; Measures; Consultant Contracts	Minor to Moderate	Possible	Low to Medium	What is the magnitude of this event? Depending on the magnitude, a shortage of workforce could be considered a moderate consequence as far as financial impact, service interruptions, and significantly impacted programs (design, construction, load ratings, maintenance, inspection etc).		

Work Group Assignment #1: Identification of Hydraulic Structures Risks (including undermanaged)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	
				Has MnDOT been managing this risk effectively?			What is the risk rating?			
					If No:					
Risks:	**Impact of not managing the risk effectively to: (you do not have to have impacts in all three areas for each risk)**			**If Yes, List control/mitigation strategies used**	**List gaps in current business protocols preventing MnDOT from managing the risk effectively**	**Ideal Mitigation Strategy(ies)**	**Consequence of Risk Occurring**	**Likelihood of Risk Occurring**	**Overall Risk Rating**	**Most Undermanaged Risk**
	Asset	**Public**	**MnDOT**							
Tunnel Failure/Collapse	Strain on Rest of Tunnel System	Trauma or Death to Traveling Public and or Residents; Increased Congestion on Other Arterials and Local System; Service Delays for Traveling Public; Increased Flooding on Roadway & Adjacent Business/Residential	Highways Closures; Loss of Public Trust/Reputation; Large, Short-Term, Immediate Financial Impacts	No	Funding for Repairs and Maintenance. Not a high priority for agency; Inspection/maint. of tunnels done by Cities (need more of a joint process, merge of priorities)	MnDOT and Communities prioritize construction funding. Detour routes established in advance; map extent of possible flooding; increase funding for rehab., data collection & inspection (determine LCC & deterioration); work with Cities to redefine management of tunnels to more of a coordinated effort	Catastrophic	Likely	Extreme	2nd Highest Tunnel Risk
Flooding and Deterioration due to lack of tunnel capacity	Increased Rate of Deterioration; Deterioration of Sandstone Layer Adjacent Tunnel Lining From Pressurized Water	Increased Flooding on Roadway & Adjacent Business/Residential; Loss of Commerce; Tunnel Failure/Collapse	Increased Flooding on Roadway; Deterioration of Tunnels & Other Assets; Loss of Public Trust; Loss of Commerce; Increased Cost to Replace at a Later Time	No	Shared water with City of Minneapolis; Based on maintenance agreement, City of Minneapolis would have cost share and have said they do not have the money	Provide new system & back charge City; City to separate its' water (as much as possible); Downsize new/modified system as much as possible to save costs	Catastrophic	Possible	High	Highest Tunnel Risk
Inability to Appropriately Manage Tunnels (i.e. lack of data, no LCC or deterioration rates; adequate inspection, etc.)	Increased Risk of Failure	Increased Travel Delays	Increased Risk of Failure; Financial Impact to Repair Over Life of Asset	Inspections	Shared maintenance agreements with City of Minneapolis; Shared water with City of Minneapolis; Minneapolis tunnels in worse condition; Frequency of inspections	MnDOT pays and charges Minneapolis interest and/or reduces funding on other projects that City wants; Put information in bridge inventory, not just HydInfra; pressure transducer; installation and monitoring	Moderate	Likely	Medium	
Culvert Failure/Collapse	Requires roadway reconstruction or repair with culvert replacement	Safety of Traveling Public (e.g. car damage, injury or death/fatalities); Service Delay; Emergency Service Disruptions; Flooding to Adjacent Properties	Considerable impact to MnDOT's reputation if fatalities would occur. Higher cost of emergency repairs compared to maintenance.	Partially, have implemented inventory and inspection program to identify bad culverts and begun repairing some pipes. Should minimize surprise failures.	Insufficient funding for adequate maintenance and repairs. Not all culverts needing repaired are fixed during construction projects. MnDOT Maintenance staffing inadequate to address drainage needs.	Culverts identified as in poor or very poor condition are fixed by MnDOT maintenance or in construction projects. Culverts identified as very poor are fixed before failures cause major repair impacts.	Major	Likely	High	Highest Culvert Risk
Lack of Culvert Capacity	Culvert and road failure (e.g. caused by high head, road overtopping, scour or piping)	Detours, delays or property damage (e.g. Flooding to Adjacent Properties)	Staff and funding needed to address problems (e.g. law suits, flood damage, road and culvert repairs and detours)	No	Insufficient resources to upsize culverts and concerns of passing additional water downstream. (e.g. permitting requirements, environmental, ROW impacts, liability)	Parties causing upsize need participate financially. Evaluations done on case by case basis but more resources will be needed. May require designing more storage and investing in flood easements. Watershed coordination.	Minor	almost certain	Medium	3rd Highest Culvert Risk
Inability to Appropriately Manage Culverts (i.e. lack of data, no LCC or deterioration rates; age, adequate inspection, etc.)	Greater likelihood of culvert failure. Higher life cycle cost.	Pays more for drainage infrastructure maintenance; potential traffic impacts, exposure to culvert failure risk. Lack of Ability/Time to Work with Partners to Actually Improve Hydraulics serving constituents.	MnDOT pays more over life cycle, more for emergency repairs, may suffer impacts to trust and confidence. May be investing inefficiently (e.g. Under or Over Investing; Inability to Leverage Appropriate Funding to Meet Targets)	Partially; MnDOT has invested heavily in inventory and condition data collection, a rigorous drainage performance measure remains to be selected. A department wide measure would result in more systematic management of the system.	Selection of a repair measure and target, and corresponding funding. Missing data in HydInfra (i.e. date built, construction as-built, repair records). Robust LCC methodology.	Funding to be able to implement a systematic maintenance approach based on targeted work , complete LCC understanding, data provided and shared by design, construction, maintenance.	Moderate	Possible	Medium	2nd Highest Culvert Risk
Inappropriately Distributing Funds or Inconsistency on Investing in Culverts	Higher likelihood of localized failures	Potential inconsistent levels of service geographically; Potentially differing risks in Safety of Traveling Public (e.g. car damage, injury or death); Service Delay; Emergency Service Disruptions; Flooding to Adjacent Properties	Districts need to make hard decisions about where to spent limited funds, backlogs of needed maintenance or repair could develop.	Unknown	Lack of funds and ability to manage culverts in a cost effective manner	More funds, better information to manage culverts with less money.	Minor	Possible	Low	
Significant Damage to Culvert Through Man-Made Event(s)	Culverts are damaged (e.g. utility installation, vehicle hits apron, damage from fire)	Bears costs ($'s, Inconvenience etc).	Costs to repair culverts.	Unknown	Difficult to predict or prevent.	Respond when event happens.	Insignificant	Likely	Low	

Work Group Assignment #1: Identification of Overhead Sign Structures & High-Mast Light Tower Structures Risks (including undermanaged)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10	
Risk of:	Impact of not managing the risk effectively to: (you do not have to have impacts in all three areas for each risk)			Has MnDOT been managing this risk effectively?			What is the risk rating?			Most Undermanaged Risk
				If Yes, List control/mitigation strategies used	If No:		Consequence of Risk Occurring	Likelihood of Risk Occurring	Overall Risk Rating	
	Asset	Public	MnDOT		List gaps in current business protocols preventing MnDOT from managing the risk effectively	Ideal Mitigation Strategy				
Lack of having a mandated process for inspection	Lower Asset Quality (Not a priority for agency so work (i.e. inspection/fixes) doesn't get completed in a timely manner	increased risk of safety and/or damage to public property (vehicles), increase in cost to public if external resources are used	Staffing; lack of public trust to know the condition of the asset	Bridge Office Structural Metals and Bridge Inspection Engineer performs inspections per technical memorandum on all TL.	Management deciding inspection is a priority. Determining which offices/functional areas will perform and be accountable for the inspections	tech memo. (similar to tower lighting); mandatory 5-year inspection cycle (this is probably a measure and/or target)	Minor	Possible	Low	
Poor contract execution (e.g., inappropriate construction installation)	Poor quality product; deteriorate at a higher rate; increased reactive maintenance.	Safety; decreased public confidence; increased service interruptions.	Staffing; Reputation; More Costs and/or Less Funding; Ability to Scope with Project	No.	Project Engineer relies on contractor to perform installation correctly. There is no understanding of the cost to repair because of poor asset installation	better quality controls (e.g. MnDOT checks) of construction work outside of edge-of-pavement-to-edge-of-pavement; better checklist to include roadside infrastructure; workshops at end of construction project	Minor	Likely	Medium	Highest OSS/TL Risk
Inability to manage to lowest life-cycle cost (e.g., preventive activities not performed on a timely basis)	Deteriorates faster (reduced service life); more reactive maintenance; higher life cycle cost.	Increased duration and frequency of service interruptions; decreased public confidence.	Lower service conditions; does not meet AASHTO light levels; increased operations resource needs	Bridge Office Structural Metals and Bridge Inspection Engineer notifies Electrical Services after pole is inspected as to what repairs are required for each pole.	Funding is rotated to where needs are to try and maintain balance; lack of data on what is optimal lowest LCC	Having an enterprise asset management system in place will help track status of asset (e.g. inspection of asset is completed by maintenance which is part of Engineering Services and fixes are performed by electrical services which is part of Operations Division. There is not a direct and clear connection to notify maint. when fixes are performed.	Minor	Likely	Medium	2nd Highest OSS/TL Risk
Significant damage to the asset through man made events (e.g., crashes, damage from construction activities etc.)	Faster deterioration due to damage to elements; decrease in life of structure	increased risk of safety and/or damage to public property (vehicles)	Increase in tort claims, increase in public complaints	MnDOT monitors roadway cameras and responds to asset damage due to crashes in timely manner; MnDOT pursues restitution with insurance companies to recoup costs		Not sure what factor of safety is being used for structural design?	Minor	Likely	Medium	
Premature deterioration of the asset	Unexpected need- more resources assigned to that asset; other preservation projects are deferred.	Safety; Potential for unsafe driving conditions.	Changed maintenance program: top needs are redefined; unanticipated resources assigned to a single asset and other priorities are deferred.	Inspections of TL keep the premature for failure of the asset to a minimum.	lack of data on what deterioration rates for OSS/TL are		Minor	Likely	Medium	
Unforeseen changes in regulatory requirements, travel demands, or technology (e.g., significant industrial growth in one region of the state, availability of new technology for conducting inspections more efficiently)	Increase in the number of structures, larger structures being built because of additional weight (larger or more elements); more complex structures due to complex traffic control devices	Increase in cost to maintain and build structures	Inquired costs because of new requirements/specs, increase in personnel time to inspect more structures, increase in technical knowledge to perform inspections		communicating hard costs when regulatory requirements are implemented; being able to determine if an additional structure is a "need" or just a "want"	Adding maintenance and inspection costs to capital costs (life cycle costs) when making planning/design decisions	Moderate	Rare	Low	
Shortage of workforce (e.g., early retirements/hiring freezes or need for additional staff to complete work tasks in a timely manner)	decrease in life of structure due to lack of inspections and maintenance	increased risk of safety and/or damage to public property (vehicles)	Inspection intervals increased or not accomplished; maintenance response time slower or not able to accomplish			Determine risk to public if MnDOT staff is decreased.	Minor	Possible	Low	3rd Highest OSS/TL Risk

Work Group Assignment #1 Results: Identified Most Undermanaged Risks

Risks:	Impact of not managing the risk effectively to: (you do not have to have impacts in all three areas for each risk)			Has MnDOT been managing this risk effectively?		
				If Yes, List control/mitigation strategies used	If No:	
					List gaps in current business protocols preventing MnDOT from managing the risk effectively	Ideal Mitigation Strategy(ies)
	Asset	Public	MnDOT			
Pavement						
Not meeting public expectations for pavement quality/condition, specifically at the local/corridor level	Strain on rest of system; economic impacts; traveler safety; higher maintenance costs	Economic (commodities) impacts; lower quality of life; traveler safety; service delays for traveling public	Reputation; higher maintenance costs; other asset maintenance is deferred.	Using money to manage to lowest lifecycle cost including routine maintenance; money distributed statewide based on need; measures & targets; balanced across entire system; MAP-21 direction (allocates $ on NHS); staging of treatments (more timely & appropriate treatments); multiple fixes at location or on corridor		More timely and appropriate staging of treatments; multiple fixes at location or on corridor (only if LCC treatment intervals modified); more systemmatic and standardized statewide approach to fixes
Local Level - Corridor (predicted or premature) NOT STATE OR DISTRICT						Better manage expectations
Inappropriately managing or not managing pavements such as frontage roads, ramps, and auxilary lanes						Increased IDIQ or BARC type projects to address localized distresses; better tracking of deterioration and condition
Bridge						
Inability to manage to lowest life-cycle cost for bridges (corollary risk: lack of or deferred funding)	Deteriorates faster (reduced bridge service life); more reactive maintenance; higher life cycle cost; manage highest needs first	Increased duration and frequency of service interruptions; decreased public confidence; bridge or route restrictions	More bridges falling into lower service conditions faster; do not meet performance targets; increased operations resource needs	BRIM; SIMS; performance measures	SIMS Maintenance Module (in progress); linking costs to maintenance tasks (Swift, SIMS and BI); SIMS, BRIM and construction cost data not linked; Preventive Maintenance Performance Measure still in development; deterioration curves; implementation and use of the multi-objective optimization tool in BrM 5.2 (in development)	Link BRIM, SIMS, Swift, contract preservation costs and BrM 5.2 in order to make appropriate management decisions; preventive maintenance performance measure; better knowledge of deterioration curves
Premature deterioration of a bridge	Unanticipated reactive maintenance or major investments required sooner; reduced service life	Increased duration and frequency of service interruptions; bridge or route restrictions; safety; decreased public confidence	Do not meet performance targets; changed maintenance program; increased operations resource needs	Inspection and maintenance tracking to try to anticipate needs; ability to track and prioritize work	SIMS Maintenance Module (in progress); deterioration curves; implementation and use of the multi-objective optimization tool in BrM 5.2 (in development)	Better inspection and maintenance tracking; better knowledge of deterioration curves; BrM 5.2
Highway Culverts						
Culvert failure/collapse	Requires roadway reconstruction or repair with culvert replacement	Safety of traveling public (e.g. car damage, injury or death/fatalities); service delay; emergency service disruptions; flooding to adjacent properties	Considerable impact to MnDOT's reputation if fatalities occur; higher cost of emergency repairs compared to maintenance.	Partially, have implemented inventory and inspection program to identify bad culverts and begun repairing some pipes. Should minimize surprise failures.	Insufficient funding for adequate maintenance and repairs. Not all culverts needing repaired are fixed during construction projects.	Culverts identified as in poor or very poor condition are fixed by MnDOT maintenance or during construction projects. Culverts identified as very poor are fixed before failures cause major repair impacts. Need a better coordinated process for fixes.
Inability to appropriately manage culverts	Greater likelihood of culvert failure; higher life cycle cost	Pays more for drainage infrastructure maintenance; potential traffic impacts, exposure to culvert failure risk; lack of ability/time to work with partners to improve hydraulics for constituents	Pay more over life cycle; higher costs for emergency repairs: impacts to trust and confidence; investing inefficiently (e.g. under or over investing; inability to leverage appropriate funding to meet targets)	Partially; MnDOT has invested heavily in inventory and condition data collection, a rigorous drainage performance measure remains to be selected. A department-wide measure would result in more systematic management of the system.	Selection of a repair measure and target, and corresponding funding. Missing data in HydInfra (i.e. date built, construction as-built, repair records). Robust LCC methodology.	Additional funding to be able to implement a systematic maintenance approach based on targeted work, complete LCC understanding, data provided and shared by design, construction, maintenance.
Lack of culvert capacity	Culvert and road failure (e.g. caused by high head, road overtopping, scour or piping)	Detours, delays or property damage (e.g. flooding to adjacent properties)	Staff and funding needed to address problems (e.g. law suits, flood damage, road and culvert repairs and detours)	No	Insufficient resources to upsize culverts and concerns of passing additional water downstream. (e.g. permitting requirements, environmental, ROW impacts, liability)	Parties causing upsize need to participate financially; evaluations could be done on case by case basis which would require more resources; may require designing more storage and investing in flood easements; watershed coordination.
Deep Stormwater Tunnels						
Flooding and deterioration due to lack of tunnel capacity	Increased rate of deterioration; deterioration of sandstone layer adjacent tunnel lining from pressurized water	Increased flooding on roadway & adjacent business/residential; loss of commerce; tunnel failure/collapse; service delays	Increased flooding on roadway; deterioration of tunnels & other assets; loss of public trust/reputation; loss of commerce; increased cost to replace at a later time	No	Shared water with City of Minneapolis; based on maintenance agreement, City of Minneapolis would have cost share and have said they do not have the money	Provide new system & back charge City; City to separate its' water (as much as possible); downsize new/modified system as much as possible to save costs
Tunnel failure/collapse because of not managing and mismanagement	Strain on rest of tunnel system	Trauma or death to traveling public and or residents; increased congestion on other arterials and local system; Service delays for traveling public; increased flooding on roadway & adjacent business/residential	Highways closures; loss of public trust/reputation; Large, short-term, immediate financial impacts	No	No funding for repairs and maintenance. Not a high priority for agency; inspection/maint. of tunnels done by Cities (need more of a joint process, merge of priorities)	MnDOT and communities prioritize construction funding. detour routes established in advance; map extent of possible flooding; increase funding for rehab., data collection & inspection (determine LCC & deterioration); work with Cities to redefine management of tunnels to more of a coordinated effort
Overhead Sign Structure & Tower Lighting						
Poor contract execution for installation of overhead sign structures and tower lighting	Poor quality product; deteriorate at a higher rate; increased reactive maintenance	Safety; decreased public confidence; increased service interruptions	Staffing; reputation; more costs and/or less funding; ability to scope with project	No.	Project Engineer relies on contractor to perform installation correctly - lack of oversight on project-by-project case; lack of understanding of costs to repair because of poor asset installation	Better quality controls (e.g. MnDOT checks) of construction work outside of edge-of-pavement-to-edge-of-pavement; better checklist to include roadside infrastructure; routine/mandatory workshops at end of construction project
Inability to manage to lowest life-cycle cost for overhead sign structures and tower lighting	Deteriorates faster (reduced service life); more reactive maintenance; higher life cycle cost	Increased duration and frequency of service interruptions; decreased public confidence	Lower service conditions; does not meet AASHTO light levels; increased operations resource needs	Bridge Office Structural Metals and Bridge Inspection Engineer notifies Electrical Services after pole is inspected as to what repairs are required for each pole.	Funding is rotated to where needs are to try and maintain balance; lack of data on what is optimal lowest LCC	Enterprise asset management system for better tracking asset status (e.g. inspection of asset is completed by maintenance which is part of Engineering Services and fixes are performed by Electrical Services which is part of Operations Division. There is not a direct and clear connection to notify maint. when fixes are performed.
Shortage of workforce for overhead sign structures and tower lighting	Decrease in life of structure due to lack of inspections and maintenance	Increased risk of safety and/or damage to public property (vehicles)	Inspection intervals increased or not accomplished; maintenance response time slower or not able to accomplish			Determine risk to public if MnDOT staff is decreased; cross training of staff (redundancy in knowledge)

Work Group Assignment #2 Detailed Instructions

During your work on identifying and prioritizing undermanaged risks, your group identified mitigation strategies that would enable MnDOT to better manage these risks. The objective of this exercise is to explore those risk mitigation strategies in more detail to help us estimate the overall return on the investment. You will do that by reviewing your risk statements and identifying costs associated with one or two mitigation strategies for each of your asset group's most undermanaged risks (as previously identified – see Excel spreadsheet). The results of this activity will be used in a workshop on November 15, 2013.

Step 1: Define your preferred mitigation strategy for addressing the risk. Be specific as to what needs to be done to better manage risk. For example, instead of saying "better manage customer expectations," it would be more specific to suggest activities such as "develop a press package to help customers set more realistic pavement performance expectations based on the fiscally-constrained environment." Your mitigation strategy should clearly convey to an outsider what will be done to reduce or eliminate the risk.

Step 2: Identify the data, resources, tools, and/or training required to enact your strategy. Without getting too hung up in the details of what will be required, prepare an estimate of the types and quantities of resources that might be needed to implement your strategy, including work force impacts, equipment purchases, software tools, and so on. For example, will you need a 2-person survey crew for 2 months of the year? Do you need an analysis tool to be able to predict asset performance? For the example given in Step 1, the response might look like this:

[Example Response: Requires a Public Information Office employee to develop a campaign using data provided from the pavement management system. Once the campaign materials are developed, the materials must be distributed via appropriate channels and future customer expectations must be monitored every other year.]

Step 3: Describe whether your strategy will reduce the likelihood of another risk identified by your group. For example, a more formal process for managing culverts should reduce the likelihood that unexpected failures will occur.

Step 4: Estimate the approximate cost of implementing the preferred mitigation strategy. Again, do not worry too much about getting your cost estimate exact. If you can adequately estimate the relative magnitude of the strategy cost, that should be close enough. In other words, we would like to know if this is a $20,000 strategy or a $200,000 strategy. Use readily available information to prepare your estimate and document how you arrived at the total cost. For calculating work force salary costs, please use an hourly unit cost of $25/hour. If it is too difficult to estimate the costs associated with your strategy, at least indicate whether your preferred strategy is a low-cost strategy (i.e. less than $250,000 annually to implement), moderate-cost strategy (i.e. between $250,000 and $800,000 annually), or a high-cost strategy (i.e. more than $800,000 annually)

Step 5: Identify whether an alternate strategy might be available that doesn't fully mitigate the risk, but lowers the overall likelihood or consequence associated with the risk. Think about alternate approaches that might not be as effective at reducing the risk, but might cost the agency less than the preferred strategy. For example, the preferred strategy for managing culverts might be to repair all culverts in poor or very poor condition. An alternate strategy might include monitoring all culverts in poor or very poor condition on a quarterly basis to track changes in conditions and to prioritize repairs. This approach won't eliminate unexpected culvert failures, but will provide a way of prioritizing the culverts that are at greatest risk.

Step 6: Estimate the cost associated with the alternate strategy. As in step 4, we are not looking for a detailed estimate, but want you to think about the resources, equipment, or tools that might be needed to implement the alternate strategy.

Step 7: For both of the strategies you've identified, identify the impact on the likelihood and consequence of the original risk should either of the strategies be adopted. This information will allow us to estimate the return on investment associated with each of the two strategies. You can use the chart below to record the changes in likelihood and consequence.

Risk 1:	**Original Risk Rating**	**Risk Ratings for Preferred Strategy** (From Step 1)	**Risk Ratings for Alternate Strategy** (From Step 6)
Likelihood of Event (Select from: Rare, Unlikely, Possible, Likely, or Almost Certain)			
Consequence of Event (Select from: Insignificant, Minor, Moderate, Major, or Catastrophic)			

Risk 2:	**Original Risk Rating**	**Risk Ratings for Preferred Strategy** (From Step 1)	**Risk Ratings for Alternate Strategy** (From Step 6)
Likelihood of Event			
Consequence of Event			

Risk 3:	**Original Risk Rating**	**Risk Ratings for Preferred Strategy** (From Step 1)	**Risk Ratings for Alternate Strategy** (From Step 6)
Likelihood of Event			
Consequence of Event			

Work Group Assignment #2: Identification of Pavement Undermanaged Risk Mitigation Strategies and Costs

Undermanaged Opportunity	Current Control/Mitigation Strategy(ies)	Previously Identified Mitigation Strategy(ies)	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7		
			Preferred Mitigation Strategy(ies)	Data, Tools Resources and/or Training Required to Make Strategy Reality	Describe if Strategy Will Reduce Likelihood of Another Risk	Estimate Approximate Cost of Preferred Mitigation Strategy(ies)	Alternate Mitigation Strategy	Estimate Approximate Cost of Alternate Strategy	Estimate Likelihood & Consequence of Strategy		
									Original Risk Rating	Preferred Strategy Rating	Alternate Strategy Rating
Pavement											
If public expectations for pavement quality or condition are not met, especially at the local/corridor level, then the agency's reputation may suffer, service delays and unsafe conditions may increase and the cost of maintenance may grow.	Using money to manage to lowest lifecycle cost including routine maintenance; money distributed statewide based on need; measures & targets; balanced across entire system; MAP-21 direction (allocates $ on NHS); staging of treatments (more timely & appropriate treatments); multiple fixes at location or on corridor	More timely and appropriate staging of treatments; multiple fixes at location or on corridor (only if LCC treatment intervals modified); more systemmatic and standardized statewide approach to fixes	1. Annually track, monitor and identify roadway segments that have been in poor condition greater than 5 years, and consistently consider when programming at the District level	Query out miles by poor with no treatments within last 5-years or some extended period of time.	Strategy will not reduce likelihood of the 2nd risk but may reduce the previous risk (likelihood) of meeting GASB 34 (previously identified risk - not under-managed)	1. 8 hours of staff time to run report and coordinate with districts during annual programming activities.	3. Turnbacks (jurisditional realignment) 4. Outreach plan or communication tool	3. $200k per mile to bring roads up to standard for realignment 4. $25k	C: Major L: Likely	C: Major L: Possible	C: Moderate L: Likely
If MnDOT does not include ramps, access roads, auxiliary lanes and frontage roads in its pavement inventory and use their condition in its pavement model, then these assets will not be included in pavement management decisions and cannot be managed to achieve the lowest lifecycle cost for all highway pavements.	No	Increased IDIQ or BARC type projects to address localized distresses; better tracking of deterioration and condition	1. Collect additional information/data in the Metro District with the use of old Material Office pavement van. 2. Build a stand alone database that will house information/data and allow for better tracking.	Use old Material Office pavement van, MS Excel or Access software for database	Strategy will not reduce likelihood of the 1st risk.	1. $100/mile 2. $2000-4000. Rough cost to put database together and communicate to districts. Cost might be more toward $10-20k if a consultant was hired.	3a. Collect data in Greater MN districts by hand, using maintenance staff. 3b. Visually collect images through video capture or windshield survey.	3a/3b. $100/mile to collect data and additional cost/time to enter information into database. This time and cost would be determined by the data (# of facilities, collection detail, etc.)	C: Minor L: Possible	C: Minor L: Unlikely	C: Minor L: Unlikely

Work Group Assignment #2: Identification of Bridge Undermanaged Risk Mitigation Strategies and Costs

			Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7 Estimate Likelihood & Consequence of Strategy		
Undermanaged Opportunity	Current Control/Mitigation Strategy(ies)	Previously Identified Mitigation Strategy(ies)	Preferred Mitigation Strategy	Data, Tools Resources and/or Training Required to Make Strategy Reality	Describe if Strategy Will Reduce Likelihood of Another Risk	Estimate Approximate Cost of Preferred Mitigation Strategy	Alternate Mitigation Strategy	Estimate Approximate Cost of Alternate Strategy	Original Risk Rating	Preferred Strategy Rating	Alternate Strategy Rating
Bridge											
If bridge inspection data, bridge model sophistication and bridge deterioration models are not accurate or complete, then it may be difficult to determine the lowest lifecycle cost strategy for bridges. **AND** **If one or more bridges deteriorate prematurely, then maintenance costs may be higher than expected and there may be unanticipated risks to structural integrity.**	BRIM; SIMS; performance measures Inspection and maintenance tracking to try to anticipate needs; ability to track and prioritize work	Link BRIM, SIMS, Swift, contract preservation costs and BrM 5.2 in order to make appropriate management decisions; preventive maintenance performance measure; better knowledge of deterioration curves Better inspection and maintenance tracking; better knowledge of deterioration curves; BrM 5.2	1. Finish development of SIMS Maintenance Module 2. Develop the Preventive Maintenance (PM) Program/Performance Measure (in progress) to verify that PM is performed at the right time. 3. Develop BI reporting tool to link SIMS and Swift (in discovery phase now). 4. Migrate inspection (and maintenance?) data to BrM 5.2 (BrM 5.2 is still in development) and create/utilize the deterioration curves. As part of this step, the CORE AASHTO elements need to be translated to the new AASHTO National Bridge Elements (NBE). 5. Link Construction Costs with Maintenance costs in BI 6. Link BRIM and BrM 5.2 7. Compare cost, age and performance trends of the bridge system to determine effectiveness of management strategy and adjust accordingly 8. Research to further identify lowest lifecycle cost (i.e. deterioration models, effectiveness of maintenance activities, products etc.)	1a. SIMS Maintenance Module is currently in development with Bentley. We have in depth maintenance data back to 2009 which needs to be migrated into the SIMS Maintenance Module. 1b. Training Required (50 Trainees + 2 instructors for 8 4-hour training sessions located around the state + curriculum development and data migration = 400 hours total) 2. Need to develop the measure. Also need collaboration from the Districts (Annual Meetings between Bridge Office Staff and District Staff) 3a. BI Bridge Maintenance tool is currently in the data discovery phase. We do not have a project assigned yet and therefore do not have any associated costs. All costs included in this strategy are estimates and may actually be higher or lower given many factors. 3b. Training (Power Users: 3 Trainees + 1 instructor for 2 full day sessions = 64 hours total; Regular Users: 29 Trainees + 1 instructor for 1 full day session = 240 hours total) 4a. Multi-state collaboration for development. $50,000 per year for 5 years for BrM 5.2 development (29 states participate) 4b. Need resources and equipment to test and implement the BrM 5.2 system. Need to develop deterioration curves from Minnesota data. 5. Need to develop a plan on how to link Construction Costs to the BI reporting tool. 6a. BRIM Development 6b. Need to develop a plan on how to integrate BRIM risk analysis into BrM 5.2. 7. Development 8a. Deck Deterioration and NBE Research is currently in progress. 8b. Other Research may be needed.	This strategy will mitigate both of the risks identified in this exercise (manage to lowest lifecycle cost and premature deterioration) as well as help to mitigate the lack of or deferred funding.	$2 Million (This represents a one time implementation cost. Following implementation, this will be a low cost strategy to maintain annually)	1. Finish development of SIMS Maintenance Module (already in progress). 2. Develop the Preventive Maintenance (PM) Program/Performance Measure (in progress) to verify that PM is performed at the right time. 3. Cost accounting tracking through existing systems (WOM, Financial Reports). These systems are not tied with maintenance data in SIMS. 4. Migrate inspection (and maintenance?) data to BrM 5.2 (BrM 5.2 is still in development) and create/utilize the deterioration curves. As part of this step, the CORE AASHTO elements need to be translated to the new AASHTO National Bridge Elements (NBE). 5. Not included in alternate mitigation strategy. 6. Use BRIM as currently developed. 7. Not included in alternate mitigation strategy. 8. Current Research	$1.4 Million (This represents a one time implementation cost. Following implementation, this will be a low cost strategy to maintain annually)	C: Moderate L: Likely	C: Minor L: Likely	C: Moderate L: Likely

Work Group Assignment #2: Identification of Hydraulic Undermanaged Risk Mitigation Strategies and Costs

Undermanaged Opportunity	Current Control/Mitigation Strategy(ies)	Previously Identified Mitigation Strategy(ies)	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7		
			Preferred Mitigation Strategy(ies)	Data, Tools Resources and/or Training Required to Make Strategy Reality	Describe if Strategy Will Reduce Likelihood of Another Risk	Estimate Approximate Cost of Preferred Mitigation Strategy(ies)	Alternate Mitigation Strategy	Estimate Approximate Cost of Alternate Strategy	Estimate Likelihood & Consequence of Strategy		
									Original Risk Rating	Preferred Strategy Rating	Alternate Strategy Rating
Highway Culverts											
Inability to manage highway culverts increases risk of failure and the life cycle cost (LCC).	Partially, MnDOT inventories and inspects highway culverts and the information is used to plan maintenance work and project scoping activities. Culvert failues are repaired when they occur.	Additional funding to be able to implement a systematic management approach based on targeted work, complete LCC understanding, data provided, shared and used by design, construction, maintenance.	1. Adopt System Condition Performance Measure (including defining target, etc.) 2. Implement Asset Management System and Data that will support LCC 3. Repair or replace Highway Culverts in accordance with Asset Management System Recommendations through Captial Projects and Maintenance work.	1. Staff time to develop and implement performance measures 2a. Funds to purchase and implement Transportation Asset Management System 2b. Staff & consultant resources to develop LCC business rules 2c. Staff & consultant resources to collect data for asset management system 3. Funding for capital and maintenance work needs to repair and replace culverts	Strategy will reduce the likelihood of road failure, interruption of service, lack of adequate capacity, and land owner drainage complaints. Strategy will also reduce the risk of not being able to support HydInfra system.	1. 200 hours staff time 2a. >$1M for software, consultant, and equipment purchase. 1000 hours staff time. 2b. $50,000 Research or consultant project. 500 hours staff time for internal rule development and training. 2c. 16,000 hours per year for highway culverts (assume around 12,000 hours currently, estimate extra 3000 hours/per year for unknown condition culverts, plus 1000 hours per year to meet inspection targets) 3. $40M per year (approximate $30M current investment, and additional $10M per year to repair or replace poor and very poor highway culverts).	Stand-alone construction projects to repair or replace poor and very poor highway culverts.	1. NA 2a. $1.25 M to implement Transportation Asset Management system (does not include LCC functionality) and 800 staff hours. 2b. NA 2c. 16,000 hours/year (no change) 3. $30M current investment + funding for additional stand-alone construction projects	C: Moderate L: Almost Certain HIGH	C: Moderate L: Possible MEDIUM	C: Moderate L: Likely MEDIUM
Deep Stormwater Tunnels											
If stormwater tunnel capacity is not adequate for a major rain event and resulting pressurization is too great, then the tunnel will be damaged or collapse, local flooding may occur, property may be damaged, and people may be killed or injured.	No	Provide new system & back charge City; City to separate its' water (as much as possible); downsize new/modified system as much as possible to save costs	1. Complete research on underground storage options, including the exploration of shallow cavern storage options for south (I-35W) tunnel. 2. Develop & implement emergency response plan for business, residential, and freeway area along floodprone I-35W south tunnel.	Consultants and funding needed	If #1 is installed, then risk will be mitigated; #2 only deals with event when it occurs.	1. $30,000 2. $15,000	1. Build I-35W south underground storage cavern.	1. $50 M	C: Catastrophic L: Likely	C. Catastrophic L. Possible Improved Credability and may lead to lower cost solution than a parallel tunnel	C. Catastrophic L. Rare
If the suggested maintenance repairs are not made in a timely manner, then the tunnels may collapse in a major rain event, and significant property damage, loss of life, or extensive service disruption may occur and significant reconstruction costs may be necessary.	Tunnels, with exception of one, have been throughly inspected once to gauge baseline condition. Repairs have been prioritized.	MnDOT and communities prioritize construction funding. detour routes established in advance; map extent of possible flooding; increase funding for rehab., data collection & inspection (determine LCC & deterioration); work with Cities to redefine management of tunnels to more of a coordinated effort	1. Inspect one remaining tunnel. 2. Put pressure tranducers in tunnels to measure pressurization. 3. Put together and implement a mandated inspection frequency (1-5 yrs.) based on tunnel/segment condition rating. 4. Include tunnels in bridge inventory. 5. Prepare plans and implement all repairs needed on south I-35W tunnel system at MnDOT cost and city to fully fund all other known repairs on all other tunnels.	Staff, priorities, funding for consultants, TH bond funding for repairs	This work will improve our credability in the event of a failure. It will strategically fix the worst tunnels repair needs. It may reduce the event of a failure by having increased information on tunnel condition - as long as funding is available for repairs when conditions warrant it.	1. $50,000 2. Estimate is being obtained. 3. $250,000 per inspection (basic walk through). 4. Process for approval would come from Metro Maintenance and CO Bridge Office Directors. Metro WRE MS4 staff would work with Metro Bridge Maintenance and CO Bridge to transfer info to forms. May need consultant assistance. 5. TH Bond funds $12 M.	1. Staff from MnDOT (likely Metro Bridge Maintenance) trained on inspections to complete them on select tunnel segments after major rain events. 2. MnDOT hires a consultant to complete inspections on each tunnel, as identified by mandated inspection guidelines. 3. Begin repairs incrementally and withhold funding to cities on other projects if proposed repair schedules are not met.	1. Training cost and inspection time required. 2. Political acceptance? Roughly $3.5 M per segment.	C: Catastrophic L: Possible	C: Catastrophic L: Possible Improved Credability	C. Catastrophic L. Rare

Work Group Assignment #2: Identification of Other Traffic Structures Undermanaged Risk Mitigation Strategies and Costs

Undermanaged Opportunity	Current Control/Mitigation Strategy(ies)	Previously Identified Mitigation Strategy(ies)	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7		
			Preferred Mitigation Strategy(ies)	Data, Tools Resources and/or Training Required to Make Strategy Reality	Describe if Strategy Will Reduce Likelihood of Another Risk	Estimate Approximate Cost of Preferred Mitigation Strategy(ies)	Alternate Mitigation Strategy	Estimate Approximate Cost of Alternate Strategy	Estimate Likelihood & Consequence of Strategy		
									Original Risk Rating	Preferred Strategy Rating	Alternate Strategy Rating
Overhead Sign Structure & High-Mast Light Tower Structures											
If tower lights and overhead sign structures are not properly installed as part of a construction project, then they may deteriorate more rapidly, and will require more subsequent maintenance.	No	Better quality controls (e.g. MnDOT checks) of construction work outside of edge-of-pavement-to-edge-of-pavement; better checklist to include roadside infrastructure; routine/mandatory workshops at end of construction project	1. Change construction specifications to require torque threshold dye washers 2. Communicate punchlist and specifications with companies that install structures and with construction inspectors.	1. Additional staff time to write the specification and update detail plan sheets; change in element used during construction. 2. Additional staff time.	Reducing the risk of poor contract execution should extend the life of the structure and reduce maintenance costs (Risk 2), thus reducing life-cycle costs.	1. One-time fee of $1000 (40 hours of staff time). Increased annual cost of $20,000/year (if additional $1000/structure @ 20 structures/year to add dye washers). 2. Increased annual cost of $5000/year (4 hours inspection per structure and 20 structures/year is 80 hours of inspection; and 120 hours of additional communication)	MnDOT Maintenance will tighten the nuts on all new structures.	One-time fee of $40,000 to purchase an additional wrench. Increased annual cost of $2000 additional staff and equipment ($100/structure at 20 structures).	C: Minor L: Likely	C: Minor L: Rare	C: Minor L: Rare
If light tower and sign structure inspection data and deterioration models are not accurate or complete, then it may be difficult to determine the lowest life-cycle cost for these assets.	Bridge Office Structural Metals and Bridge Inspection Engineer notifies Electrical Services after pole is inspected as to what repairs are required for each pole.	Enterprise asset management system for better tracking asset status (e.g. inspection of asset is completed by maintenance which is part of Engineering Services and fixes are performed by Electrical Services which is part of Operations Division. There is not a direct and clear connection to notify maint. when fixes are performed.	1. Implement TAMS that includes a work order, resource, and materials cost tracking module. 2. Report annually on life-cycle cost and identify and implement refined/additional strategies to reduce costs.	1. Additional staff and/or consultant time to implement new software system. 2. Additional staff time to report annual performance.	Managing OSS/TL structures to lowest LCC cannot occur if Risk 1 is not mitigated.	1. One-time fee of $250,000 to add structures data into TAMS software (staff time). Increased annual maintenance and user costs of $100,000/year for software. 2. Increased annual cost of $2000/year (80 staff hours).	1. Maintain status quo with replacement cycle for OSS/TL, which is 40-50 years. 2. When OSS/TL due for replacement, remove and replace with 6-8 standard lights or ground mount overhead. 3. Conduct research that will better define/determine deterioration rates and collect other addtional info.	Overhead structure life cycles could be doubled; thereby reducing costs. Amount unknown.	C: Minor L: Likely	C: Minor L: Rare	C: Minor L: Likely
If MnDOT is unable to provide a sufficient number of workers to maintain high-mast light tower structures or overhead sign structures, then inspections, maintenance, repairs and replacement may fall short of service standards.		Determine risk to public if MnDOT staff is decreased; cross training of staff (redundancy in knowledge)	1. Adopt a MnDOT policy/technical memo requiring a 5-year inspection frequency for all overhead structures. 2. Report annually on inspection frequency results. 3. Create a training program for inspecting and maintaining structures, develop inspection forms, develop clear condition rating criteria. 4. Gain efficiencies by using mobile technology in the field	1-3. Additional staff time. 4. Additional equipment expense.	Adopting a policy/technical memo of inspecting and reporting will help mitigate Risk 1.	1. One-time cost of $1000 (40 hours staff time) to write policy. 2. Increased annual cost of $1000 (40 hours/year staff time) to report on performance. 3. One-time cost of $8000 (320 staff hours). Increased annual cost of $2000/year (80 hours/year staff time) to train. 4. Increased annual cost of $10,000/year to use mobile handheld devices.	1. Use consultants to perform work. 2. Increase inspection intervals (Strategies can be either/or/both)	An average of $800/structure was previously paid for external inspection. Internal inspections cost roughly $100/structure.	C: Minor L: Possible	C: Minor L: Rare	C:Minor L: Rare

Chapter 6

LIFE-CYCLE COST CONSIDERATIONS: SUPPLEMENTAL INFORMATION

LIFE-CYCLE COST CONSIDERATIONS: SUPPLEMENTAL INFORMATION

Overview

This chapter provides a detailed description of the various processes involved in analyzing the life-cycle costs associated with the asset classes discussed in the TAMP. Two aspects of life-cycling costing are documented: 1) the data used to conduct the analysis and the process for gathering the information, and 2) the metrics and assumptions used in the analysis. In addition to the documentation of the tools used to model life-cycle strategies, examples (attachments) are provided at the end of the chapter.

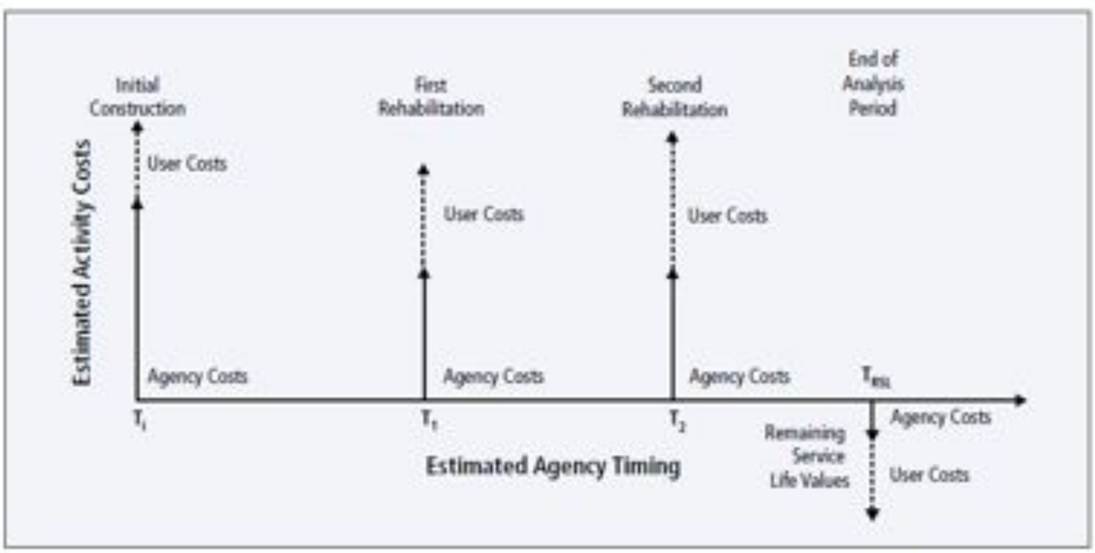
Process

The inputs for conducting a Life-Cycle Cost Analysis (LCCA) are presented first, followed by the key metrics/terms associated with an LCCA. The LCCA procedures used in developing the TAMP are then documented.

LCCA FUNDAMENTALS AND ANALYSIS COMPONENTS

The basic LCCA process requires the analyst to first define the schedule for initial and future activities associated with a specific strategy for managing an asset. Next, the costs associated with each of these activities are defined. The typical activity schedule and associated costs are used to develop a life-cycle cost stream (an example is shown in figure 6-1). Life-cycle cost stream diagrams are typically used in project-level LCCA, however, the same fundamental principles also apply to a network-level LCCA. Instead of programming treatment cycles and costs associated with a specific project, expert opinion provided by the asset Work Groups was used to estimate the same metrics at the network level (which were then scaled down to a unit level – e.g. costs per bridge or per lane-mile of pavement – to allow for comparison of life-cycle costs between various asset categories included in the TAMP).

Figure 6-1: Projected Life-Cycle Cost Stream Diagram[1]



Project-level LCCA typically includes both agency costs (direct costs to the agency as a result of the construction operations) and user costs (costs not directly borne by the agency but that affect the agency's customers, such as traffic delays during construction or maintenance activities, and can impact customer perceptions of agency performance). However, since a network-level LCCA was conducted as a part of the TAMP, user costs were not considered due to the significant variability and uncertainty that exists from project to project.

Key inputs required for conducting a network-level LCCA include:

- **Asset Condition Deterioration Rates**: The rate at which the condition of the asset deteriorates over time with and without the application of routine, reactive, and preventive maintenance treatments.
- **Treatment Types, Costs, and Cycles**: The various types of treatments applied to an asset over its life-cycle, including the type of the treatment (whether it is a routine maintenance, reactive maintenance, preventive maintenance, or major rehabilitation/replacement/reconstruction activity); the condition level (e.g. Good, Fair, or Poor) when the treatment is applied; and the resulting condition level after the application of the treatment; typical treatment costs; and treatment cycles.

This information was gathered through an assignment (discussed later) that was distributed to each of the asset Work Groups.

KEY METRICS/TERMS ASSOCIATED WITH LCCA

The key terms/metrics associated with the LCCA conducted in the TAMP are:

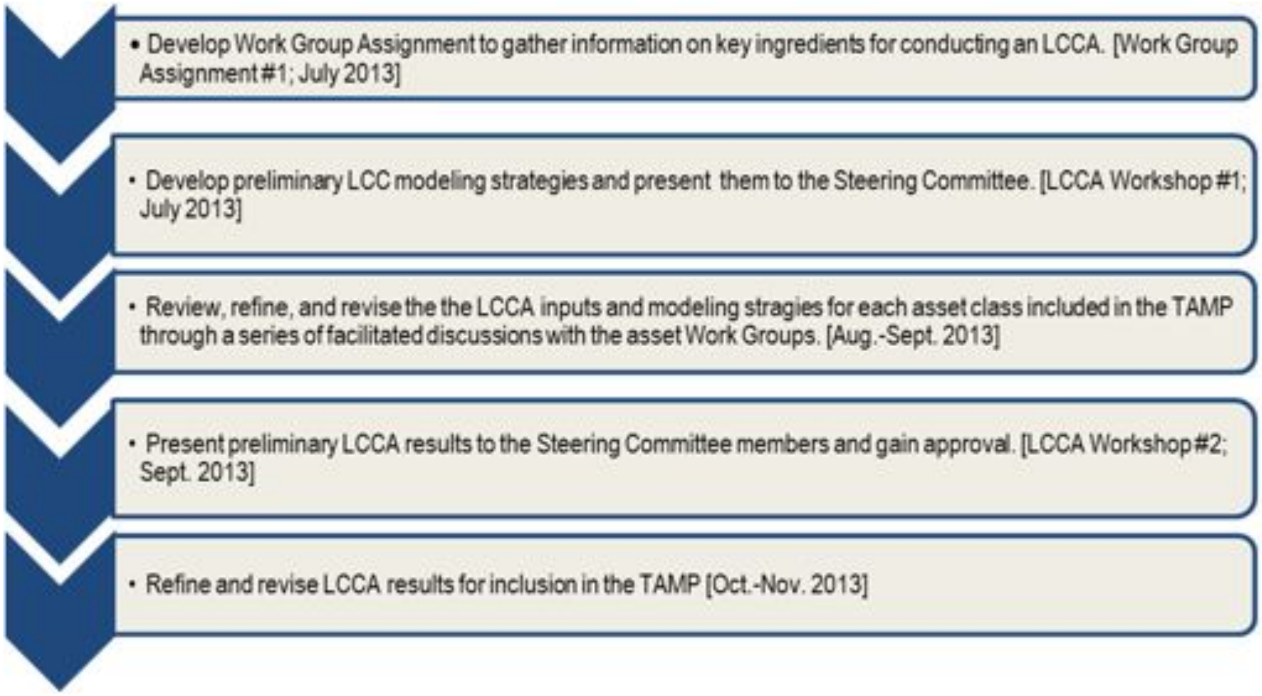
- **Analysis Period**: The timeframe over which the LCCA is performed. Theoretically, once a section of state highway is built, the agency is responsible for all future costs to keep that road in service, including the costs to reconstruct components of the road when they reach the end of their physical lives. However, because of discounting, costs in the far future have very little effect on any decisions made during the 10-year period covered by the TAMP. Forecasts of future deterioration and future needs become very unreliable if these predictions are extended too far into the future. In best practice, the analysis period of a life-cycle cost analysis should be as short as possible while still satisfying the following criteria:
    - Long enough that further costs make no significant difference in the results.
    - Long enough that at least the first complete asset replacement cycle is included.

  The reason for the second criterion is that replacement costs are typically much larger than any other costs during an asset's life, so these costs can remain significant even if discounted over a relatively long period. A fair comparison of alternatives should therefore include at least the first replacement cycle for each of the alternatives being compared.
- **Discount Rate**: Future costs converted into present day dollars using an economic technique known as "discounting". MnDOT's policy is to analyze all investments using a *real annual discount rate*, which is currently 2.2 percent. The term "real" means that the effects of inflation are removed from the computation in order to make the cost tradeoffs easier to understand.
- **Life-Cycle Cost (in today's dollars)**: The total cost of asset ownership over the analysis period when the costs incurred in future years are converted to current dollars.
- **Future Maintenance Costs as a Percent of Initial Investment**: The total future agency costs (including maintenance, rehabilitation, and inspection, but not operations costs) as a fraction of the initial construction cost of the asset. This value represents the future cost commitment that MnDOT makes for every dollar spent on a capital project.
- **Equivalent Uniform Annual Cost**: The analysis method that shows the annual costs of a life-cycle management strategy if they occurred uniformly throughout the analysis period.

LIFE-CYCLE COST ANALYSIS PROCEDURE USED IN THE TAMP

The step-by-step approach used in analyzing life-cycle costs for the TAMP is illustrated in Figure 6-2.

Figure 6-2: TAMP Life-Cycle Analysis Process



WORK GROUP ASSIGNMENT #1: COMPILE DATA ON KEY INPUTS FOR LCCA (JULY 2013)

As discussed above, an assignment was distributed to each asset Work Group to compile the key inputs required to conduct a network-level LCCA. The inputs included asset condition deterioration rates, treatment types, treatment costs, and treatment cycles. The assignment was completed by each Work Group and a copy of the results is provided at the end of this chapter. The Work Group assignment was followed by a workshop (discussed in the next section) to discuss the modeling strategies and gain input, feedback, and buy-in from the TAMP Steering Committee.

LCCA WORKSHOP #1: FINALIZE LCCA METHODOLOGY FOR TAMP (JULY 2013)

This workshop built upon the data gathered during the Work Group assignment (discussed above) to finalize the deterioration rates, unit costs, and treatment strategies for each asset. Topics covered during this workshop included:

- The level of detail required to complete the assignment.
- The development of asset deterioration rates.
- Actual versus desired maintenance strategies.
- Definitions of various condition categories and performance metrics (where none existed).
- Process changes to better incorporate whole life costing into investment decisions, which involved:
    - Identifying appropriate planned maintenance regimes to ensure assets met design lives in a cost-effective manner.
    - Capturing information in computerized systems to assist in the analysis of current and future planning activities.

The major decision made during this workshop was that representative examples would be used to characterize the life-cycle strategies for each asset included in the TAMP. However, the representative examples would be based on detailed life-cycle cost calculations computed using actual MnDOT data. It was decided that the life-cycle portion of the TAMP would serve to:

- Describe life-cycle costs and explain why they are important.
- Explain typical MnDOT infrastructure life-cycle costs using examples of deterioration rates and preservation cycles.
- Describe strategies for managing assets over their whole lives, from inception to disposal, illustrating the use of a sequence of activities, including maintenance and preservation treatments. Illustrate how these actions are helpful in delaying or slowing deterioration and maximizing the service life of an asset.
- Document the tools that MnDOT has available to help forecast life-cycle costs for some assets.
- Document typical life-cycle cost of the assets included in the TAMP.
- Explain the commitment and steps MnDOT is taking to improve its effectiveness in minimizing life-cycle costs.
- Document the typical life-cycle cost of adding a new lane-mile of roadway and document a process for considering future maintenance costs when evaluating potential roadway expansion projects.

Following this workshop, several facilitated teleconferences were held with the Work Groups to review, refine, and revise the LCCA inputs and modeling strategies used in the TAMP and to develop preliminary asset life-cycle costs.

LCCA WORKSHOP #2: PRESENT PRELIMINARY LCCA RESULTS AND GAIN FEEDBACK FROM STEERING COMMITTEE (SEPTEMBER 2013)

The preliminary life-cycle costs developed for each asset were presented at this meeting to gain critical feedback from the TAMP Steering Committee and identify additional required information or analysis. The Steering Committee provided valuable suggestions for how the life-cycle costing strategies could be presented in the TAMP. The input and feedback from this meeting was used to finalize the LCCA results for the TAMP.

Supporting Data and Documentation

This section presents the LCCA assumptions and tools used to conduct the network-level LCCA.

LCCA INPUTS AND ASSUMPTIONS

As discussed in the TAMP, three LCCA modeling strategies were used to represent “Typical”, “Worst-First”, and “Desired” treatment strategies. The “Typical” strategy reflects MnDOT’s current practices for managing the assets and the “Worst-First” strategy assumes that no treatments are applied until the complete replacement of the asset when it deteriorates to a Poor condition. The “Desired” strategy (established only for pavements due to a lack of sufficient data for bridges, hydraulic infrastructure, overhead sign structures, and high-mast light tower structures) corresponds to the strategy that MnDOT aspires to adopt in order to further reduce total life-cycle costs.

PAVEMENTS

The key inputs and assumptions specific to pavements are summarized below:

- Analysis Period: 70 years; Discount Rate: 2.2 percent
- All costs presented in dollars per lane-mile
- Only direct agency costs considered in the LCCA model; inspection costs and other operational costs like debris removal, snow and ice removal, etc. not included.

- Flexible pavements and rigid pavement LCCA modeled separately and overall life-cycle costs combined into a single composite value based on weighted averages of percent of rigid and flexible pavements in MnDOT's roadway network (11 percent rigid pavements, 89 percent flexible pavements)
- Routine and reactive maintenance costs included in the LCCA model based on the following:
  - MnDOT spent approximately $1.4 Million in 2012 (in the Minneapolis-St. Paul Metro Region). This value was used to extrapolate costs for the pavement network considered in the LCCA.
  - Investments made by pavement condition category could not be determined; therefore, weighting factors were applied to maintenance costs (for each of the three pavement condition categories: Good, Fair, Poor) based on expert input from the Work Groups. The final weighting factors (Good: 0.8; Fair: 1.2; Poor: 1.8) resulted in the following maintenance costs per condition category: Good: $2,340 per lane-mile; Fair: $3,480 per lane-mile; Poor: $5,229 per lane-mile.

The assumptions specific to the "Worst-First" strategy for pavements are summarized below:

- **Flexible Pavements**: the end-of-life activity is expected to occur between 15 and 25 years, with a "most likely" age of 25 years when no preventive maintenance is performed. The end-of-life activity is expected to cost anywhere between $210,000 per lane-mile for a full-depth reclamation (FDR) activity to $2 million per lane-mile for complete reconstruction, with the typical cost being $210,000 per lane-mile.
- **Rigid Pavements**: the end-of-life activity is expected to occur between 25 and 35 years, with a "most likely" age of 30 years when no preventive maintenance is performed. The end-of-life activity is expected to cost anywhere between $450,000 per lane-mile for an unbonded overlay to $2 million per lane-mile for complete reconstruction, with the typical cost being $450,000 per lane-mile.

Figure 6-3 summarizes the "Typical" strategy used to manage flexible pavements and Figure 6-4 summarizes the "Desired" strategy for managing flexible pavements. Figure 6-5 summarizes the life-cycle management strategy for rigid pavements (the "Typical" and "Desired" strategies are the sam for rigid pavements).

Figure 6-3: "Typical" Life-Cycle Management Strategy for Flexible Pavements (Mill and Overlay Strategy)

Typical Pavement Age* (yrs)	Pavement Age Range** (yrs)	Treatment	Typical Condition When Applied	Typical Cost ($/ln-mi)***	Cost Range ($/ln-mi)***
0	0	Initial Construction	-	$657,500#	$210,000 - $2,000,000
8	6-10	Crack Treatment	Good	$6,000	$3,000 - $10,000
12	10-14	Surface Treatment	Good	$15,000	$10,000 - $30,000
20	18-22	Mill & Overlay (1st Overlay)	Fair	$155,000*	$145,000 - $175,000
24	21-25	Crack Treatment	Good	$6,000	$3,000 - $10,000
26	25-29	Surface Treatment	Fair	$15,000	$10,000 - $30,000
35	33-35	Mill & Overlay (2nd Overlay)	Fair	$155,000	$145,000 - $175,000
39	36-40	Crack Treatment	Good	$6,000	$3,000 - $10,000
41	39-43	Surface Treatment	Fair	$15,000	$10,000 - $30,000
47	45-49	Mill & Overlay (3rd Overlay)	Poor	$155,000	$145,000 - $175,000
51	49-53	Crack Treatment	Good	$6,000	$3,000 - $10,000
53	51-55	Surface Treatment	Fair	$15,000	$10,000 - $30,000
57	55-59	Mill & Overlay (4th Overlay)	Poor	$155,000	$145,000 - $175,000
61	59-63	Crack Treatment	Good	$6,000	$3,000 - $10,000
63	61-65	Surface Treatment	Fair	$15,000	$10,000 - $30,000
65	63-67	Mill & Overlay (5th Overlay)	Poor	$155,000	$145,000 - $175,000
68	66-70	Crack Treatment	Good	$6,000	$3,000 - $10,000
70	68-72	Reconstruction	Fair	$657,500#	$210,000 - $2,000,000

Notes:
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided
#Value based on assumption that typically, 75% of the projects involve FDR and 25% involve complete reconstruction

Figure 6-4: "Desired" Life-Cycle Management Strategy for Flexible Pavements (FDR strategy)

Typical Pavement Age* (yrs)	Pavement Age Range** (yrs)	Treatment	Typical Condition When Applied	Typical Cost ($/ln-mi)***	Cost Range ($/ln-mi)***
0	0	Initial Construction	-	$657,500[#]	$210,000 - $2,000,000
8	6-10	Crack Treatment	Good	$6,000	$3,000 - $10,000
12	10-14	Surface Treatment	Good	$15,000	$10,000 - $30,000
20	18-22	Mill & Overlay (1st Overlay)	Fair	$155,000	$145,000 - $175,000
23	21-25	Crack Treatment	Good	$6,000	$3,000 - $10,000
27	25-29	Surface Treatment	Fair	$15,000	$10,000 - $30,000
35	33-35	Mill & Overlay (2nd Overlay)	Fair	$155,000	$145,000 - $175,000
38	36-40	Crack Treatment	Good	$6,000	$3,000 - $10,000
43	41-45	Surface Treatment	Fair	$15,000	$10,000 - $30,000
50	47-53	FDR/Reconstruction	-	$657,500[#]	$210,000 - $2,000,000
58	56-60	Crack Treatment	Good	$6,000	$3,000 - $10,000
62	60-64	Surface Treatment	Good	$15,000	$10,000 - $30,000
70	68-72	Mill & Overlay (1st Overlay after FDR/Reconstruction)	Fair	$155,000	$145,000 - $175,000

Notes:
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided
[#]Value based on assumption that typically, 75% of the projects involve FDR and 25% involve complete reconstruction

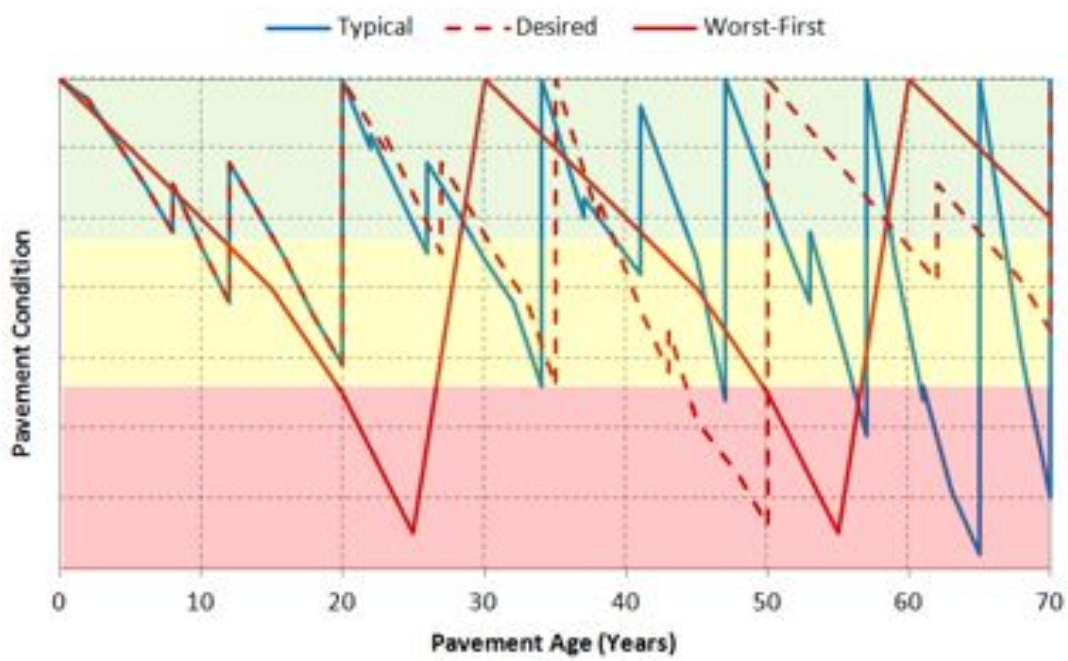
Figure 6-5: Life-Cycle Management Strategy for Rigid Pavements

Typical Pavement Age* (yrs)	Pavement Age Range** (yrs)	Treatment	Typical Condition When Applied	Typical Cost ($/ln-mi)***	Cost Range ($/ln-mi)***
0	0	Initial Construction	-	$450,000	$450,000 - $2,000,000
10	6 - 20	Reseal joints and partial depth repairs	Good	$10,000	$5000 - $15,000
16	13 - 31	Minor CPR (some full depth repairs)	Fair	$80,000	$55,000 - $80,000
26	8 - 26	Major CPR (and grinding)	Fair	$230,000	$135,000 - $230,000
50	46-54	Unbonded Overlay/Reconstruction	Poor	$450,000	$450,000 - $2,000,000
60	56 - 70	Reseal joints and partial depth repairs	Good	$10,000	$5000 - $15,000
66	63-81	Minor CPR (some full depth repairs)	Fair	$80,000	$55,000 - $80,000

Notes:
The Pavement Work Group indicated that the desired and typical life-cycle strategies are fairly close for rigid pavements and recommended using the same values for both
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided

An illustration of the deterioration models representing pavement performance over the 70-year analysis period for the three strategies considered is provided in Figure 6-6.

Figure 6-6: Deterioration Models for Various LCCA Scenarios (Pavements)



BRIDGE STRUCTURES (BRIDGES AND LARGE CULVERTS)

The key inputs and assumptions specific to bridge structures are summarized below:

- Analysis Period: 200 years; Discount Rate: 2.2 percent
- Markov models used to model condition deterioration based on expert input from the Bridge Work Group
- All costs presented in dollars per bridge and dollars per square foot (deck area)
- Routine maintenance activities applied to all bridges in appropriate condition, on a scheduled basis to slow the rate of deterioration
- Corrective action is used to repair defects and prevent further deterioration. Activities that fall under this category are considered to be infeasible when the structure is in Poor condition.
- Rehabilitation and replacement activities are performed when the service life of all or part of the structure cannot be extended. This activity is generally performed when the structure is in Poor condition.

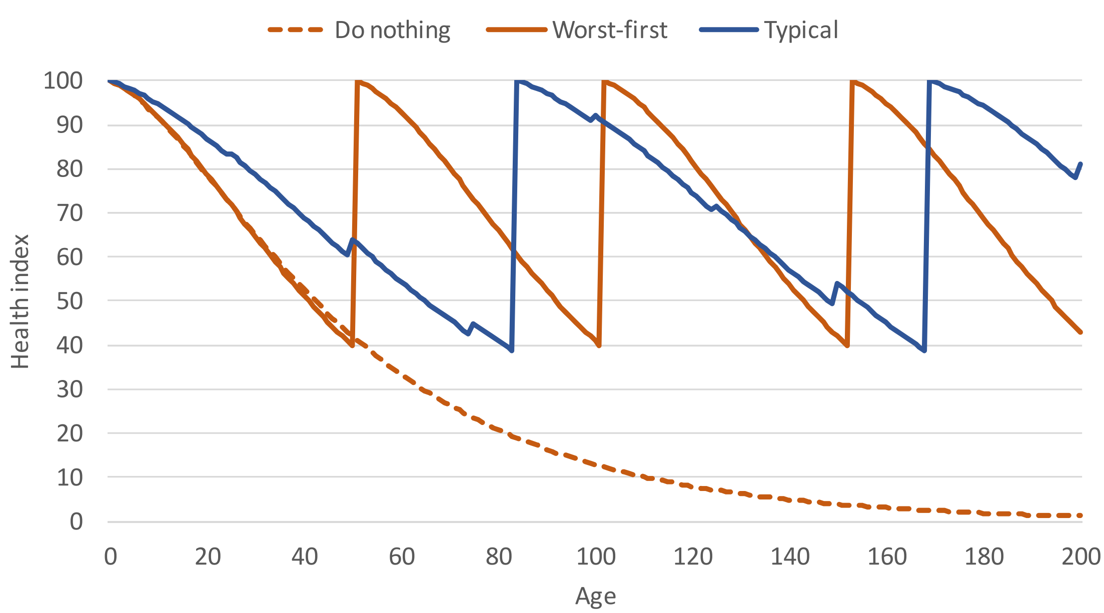
The costs and treatment strategies used in the LCCA model for bridge structures are summarized in Figure 6-7.

Figure 6-7: Costs and Treatment Strategies Used in the LCCA Model for Bridge Structures

Treatment	$/Bridge	% Bridges Acted Upon Annually			
		Good	Satisfactory	Fair	Poor
Routine Maintenance: Bridge Decks					
Joint sealing	$1,529	13%	13%	13%	
Deck sealing	$37,406	14%	14%	14%	
Crack Sealing	$1,500	20%	20%	20%	
Routine Maintenance: Bridge Superstructures					
Inspection	$1,111	60%	60%	60%	60%
Flushing	$500	75%	75%	75%	75%
Lube Bearings	$26,600	0.1%	0.2%		
Routine Maintenance: Bridge Culverts					
Inspection	$1,111	60%	60%	60%	60%
Corrective Action: Bridge Decks					
Joint repair (patch)	$38,215		1%	2%	
Deck repair	$16,833		2%	35%	15%
Overlay	$130,921			5%	2%
Rail repair/replace	$127,705		1%	5%	
Corrective Action: Bridge Substructures					
Patching	$56,070			10%	15%
Slope paving repair	$26,166		1%	1%	
Erosion/Scour Repair	$25,000			5%	5%
Corrective Action: Bridge Superstructures					
Spot Painting	$19,500		2%	5%	
Full Painting	$377,480		3%	5%	
Patching	$30,000		1%	3%	5%
Repair/Replace bearings	$46,549				5%
Repair Steel	$50,000			2%	5%
Corrective Action: Bridge Culverts					
Patching	$12,104			5%	10%
Rehab and Replacement: Bridge Decks					
Redeck	$1,122,184				5%
Rehab and Replacement: Bridge Substructures					
Replace Elements	$100,000				1%
Rehab and Replacement: Bridge Superstructures					
Replace Elements	$100,000				1%
Replace Structure	$2,702,941				20%
Rehab and Replacement: Bridge Culverts					
Replacement	$250,000				25%

An illustration of the deterioration models describing the performance of bridge structures over the 200-year analysis period is provided in Figure 6-8.

Figure 6-8: Deterioration Models for Various LCCA Scenarios (Bridge Structures)



CENTERLINE CULVERTS AND STORMWATER TUNNELS

The key inputs and assumptions specific to centerline culverts and stormwater tunnels are summarized below:

- Analysis Period: 200 years; Discount Rate: 2.2 percent
- Markov models used to model condition deterioration based on expert input from the Hydraulics Work Group
- All costs presented in dollars per structure
- Routine maintenance activities applied to all structures in appropriate condition, on a scheduled basis to slow the rate of deterioration
- Corrective action is used to repair defects and prevent further deterioration. Activities that fall under this category are infeasible when the structure is in Poor condition.
- Rehabilitation and replacement activities are performed when the service life of all or part of the structure cannot be extended. This activity is generally performed when the structure is in Poor condition.

The costs used in the LCCA model for centerline culverts and stormwater tunnels are summarized in Figure 6-9.

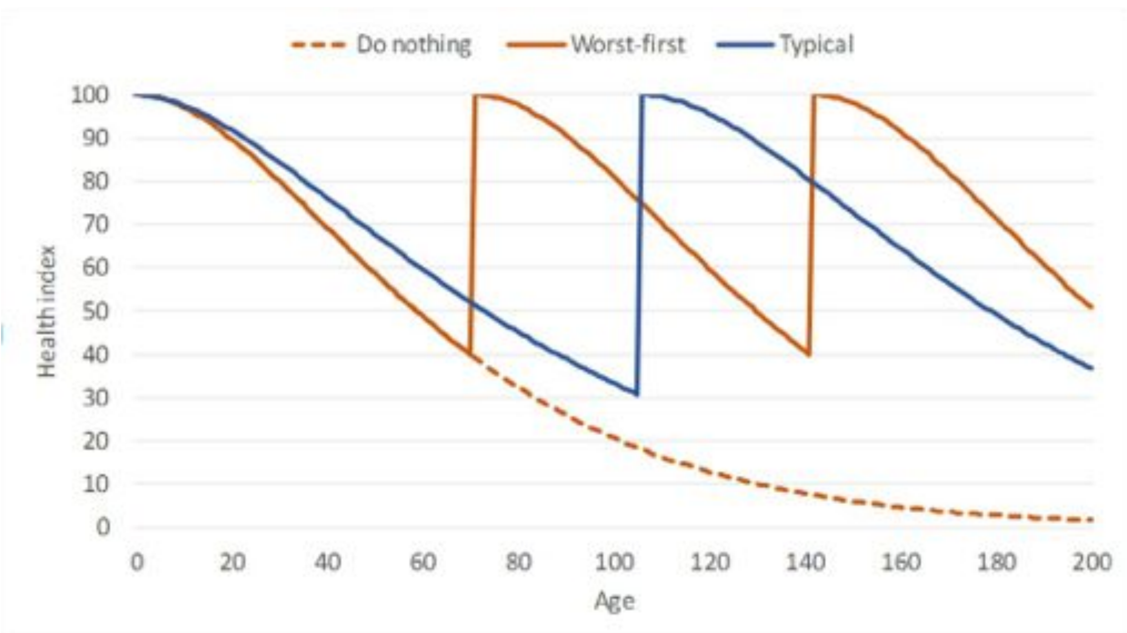
Figure 6-9: Life-Cycle Management Strategy for Centerline Culverts and Stormwater Tunnels

Treatment	$/Bridge	% Bridges Acted Upon Annually			
		Good	Satisfactory	Fair	Poor
Routine Maintenance: Centerline Culverts					
Inspection	$62	25%	25%	25%	25%
Cleaning	$100	10%	10%	10%	10%
Routine Maintenance: Stormwater Tunnels					
Inspection	$200,000	25%	25%	25%	25%
Corrective Action: Centerline Culverts					
Reset ends	$2,695		1%	2%	1%
Joint repair	$1,429		1%	1%	1%
Pave invert	$804			2%	1%
Corrective Action: Stormwater Tunnels					
Fill Voids and Cracks	$3.5 M				
Rehab and Replacement: Centerline Culverts					
Slipliner	$8,664				1%
CIPP	$6,418				2%
Replace - Trench	$32,235			1%	5%
Replace - Jack	$35,888			1%	2%
Rehab and Replacement: Stormwater Tunnels					
Replacement	$5,099,500				1%

Illustrations of the deterioration models describing the performance of centerline culverts and stormwater tunnels over the 200-year analysis period are provided in Figures 6-10 and 6-11, respectively.

Figure 6-10: Deterioration Models for Various LCCA Scenarios (Centerline Culverts)

Figure 6-11: Deterioration Models for Various LCCA Scenarios (Stormwater Tunnels)



OVERHEAD SIGN STRUCTURES (OSS) AND HIGH-MAST LIGHT TOWER STRUCTURES (HMLTS)

The key inputs and assumptions specific to overhead sign structures and high-mast light tower structures are summarized below:

- Analysis Period: 100 years; Discount Rate: 2.2 percent
- All costs presented in dollars per structure

- Inspection costs are included in the LCCA model because they are considered an important maintenance activity. Other costs, such as traffic control and mobilization, were not explicitly considered.
    - Average inspection costs for OSS: $950/structure (applied on a 4 year cycle)
    - Average inspection costs for HMLTS: $1000/structure (applied on a 5 year cycle)

The "Worst-First" strategy for OSS and HMLTS involved the replacement of the structure on a 40-year cycle with routine inspections and minimal maintenance activities. The typical life-cycle management strategies used in the LCCA model for OSS and HMLTS are summarized in Figures 6-12 and 6-13, respectively.

Figure 6-12: "Typical" Life-Cycle Management Strategy for OSS

Typical Age (yrs)	**Age Range (yrs)**	**Treatment**	**Treatment Cycle (yrs)**	**Typical Condition When Applied**	**Typical Cost ($/structure)**	**Cost Range ($/structure)**
0	0	Initial Cost of Structure	100	Poor	$85,000	$60,000 - $110,000
4	3 - 5	Tighten Nuts	8	Poor	$200	$200 - $400
8	6 - 8	Remove Grout	8	Poor	$1,000	$800 - $1,200
20	15 - 25	Re-grade footing, replace weld, remove catwalks/lighting, new mounting posts	20	Poor	$3,000	$1700 - $6000
40	35 - 45	Replace foundation or replace truss or other elements	40	Poor	$25,000	$8,000 - $30,000
100	N/A	End of Analysis Period	N/A	N/A	N/A	N/A

Figure 6-13: "Typical" Life-Cycle Management Strategy for HMLTS

Typical Age (yrs)	Age Range (yrs)	Treatment	Treatment Cycle (yrs)	Typical Condition When Applied	Typical Cost ($/structure)	Cost Range ($/structure)
0	0	Initial Cost of Structure	100	-	$40,000	$30,000 - $60,000
5	3 - 7	Routine Maintenance	5	Fair	$500	$200 - $1000
100	N/A	End of Analysis Period	N/A	N/A	N/A	N/A

LCCA TOOLS USED

The Federal Highway Administration's RealCost tool[1] was used to conduct the network-level life-cycle cost analyses for pavements, OSS, and HMLTS. The bridge structures and hydraulic infrastructure models were developed specifically for this study. Examples of several of these models are included at the end of the chapter.

[1] FHWA RealCost Tool. (Web Link)

LIFE-CYCLE COST CONSIDERATION WORKSHOP
WORK GROUP ASSIGNMENT #1 (RESULTS)

LIFE-CYCLE COST CONSIDERATION WORKSHEET - PAVEMENTS

Pavement Subset (ex: NHS): All State Trunk Highways (NHS and Non-NHS, IS, US, MN)

Deterioration Rates

On average, what is the shortest length of time (in years) before these pavements are at a condition when they should be reconstructed (assuming no other capital improvements are conducted)? 15 years

On average, what is the longest length of time (in years) before these pavements are at a condition when they should be reconstructed (assuming no other capital improvements are conducted)? 40 years

On average, what would you estimate to be the most typical length of time for the asset to reach a condition when it should be reconstructed (assuming no other capital improvements are conducted)? 25 years

Does the point at which pavements needed to be reconstructed equate to your Poor condition category? (Yes or No) If No, please comment Yes

Inspection Costs

What is the estimated average annual cost to collect and process pavement condition data so it can be used for reporting performance?

Average annual collection/processing costs: $37 per roadway mile

Treatment Costs

Five categories of repair are listed in tables P-1 and P-2, for flexible and rigid pavements respectively. Composite pavements should be considered to be rigid pavements that have received a treatment. For each of the repair categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor), and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. **Be sure to indicate the units used for your costs**.

Table P-1. Typical treatments and costs for flexible pavements.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., G/F/P)	Most Likely Condition After Treatment	Typical Cost Range ($/lane-mile)	Most Representative Cost ($/lane-mile)
Preventive Maintenance	Chip Seal Crack Seal Micro-surface	Good	Good	$3K-$30K	$15K (Chip Seal)
Minor Rehabilitation	Thin Mill/OL Rut Fill	Fair	Good	$55K-$75K	$75K (Thin M/O)
Major Rehabilitation	Medium Mill/OL Thick Mill/OL CIR	Fair/Poor	Good	$145-$175K	$155K (Med M/O)
Reconstruction	Reconstruction Reclaim	Poor	Good	$210K-$2M	$210K (Reclaim)

Table P-2. Typical treatments and costs for rigid pavements.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., G/F/P)	Most Likely Condition After Treatment	Typical Cost Range ($/lane-mile)	Most Representative Cost ($/lane-mile)
Preventive Maintenance	Joint Seal Diamond Grind	Good/Fair	Good	$20K-$30K	$30K (Grind)
Minor Rehabilitation	Minor CPR Minor CPR/Grind	Fair	Good	$55K-$80K	$80K (Minor CPR/Grind)
Major Rehabilitation	Major CPR/Grind Thick OL	Fair/Poor	Good	$125K-$230K	$230K (Major CPR/Grind)
Reconstruction	Reconstruction Unbonded OL	Poor	Good	$450K-$2M	$450K (Unbonded)

Treatment Cycles

Tables P-3 and P-4 are provided for you to enter the treatment cycles for both flexible and rigid pavements within this category of pavements. For each type of pavement, enter the following information:

- Column A: The type of activity that is applied. You can enter a category of treatments or a specific treatment.
- Columns B and C: The range of years in which the treatment is first applied. In column B identify the range of years in which the first application of this treatment is typically applied in your agency. In column C enter the range of years in which you think the treatment should be applied if funding were not an issue.

- Columns D and E: The year in which the treatment is most commonly applied. Instead of entering a range, identify the single age at which the treatment is typically applied for the first time in column D (this may be the mean or median in a set of values). In column E enter the age at which you think the treatment should be applied for the first time.
- Columns F and G: The typical application cycle for that treatment. In column F enter the typical frequency with which the treatment is applied by your agency. In column G enter the preferred treatment cycle. Once you have entered a treatment cycle, you do NOT need to enter the treatment in the table again. For instance, in the example, crack sealing is typically applied first applied in year 8 and then in year 13, since it is applied on a 5-year cycle.

Table P-3. Flexible pavement treatment cycle.

Column A **Activity**	**Range of Years During Which the Treatment is First Applied**		**Year in Which the Treatment is Most Commonly Applied**		**Application Cycle (in years)**	
	Column B Typical	*Column C* Desired	*Column D* Typical	*Column E* Desired	*Column F* Typical	*Column G* Desired
Initial Construction			0	0		
Crack Seal	3 - 5		8	8		
Chip Seal	4 - 8		12	12		
Medium Mill/OL	10 - 20		20	20		
Crack Seal			23	23		
Chip Seal			27	27		
Medium Mill/OL			35	35		
Add more rows if necessary						
End of Life Reconstruction			50	∞		

Table P-4. Rigid pavement treatment cycle.

Activity	Typical Range of Years During Which the Treatment is Applied		Most Typical Year in Which the Treatment is Applied		Application Cycle (in years)	
	Typical	Desired	Typical	Desired	Typical	Desired
Initial Construction			0	0		
Reseal joints & partial depth repairs	6 - 20		17	17		
Minor CPR and some full depth repairs	13 - 31		27	27		
Major CPR/grind	8 - 26		40	40		
Add more rows if necessary						
End of Life Reconstruction			50	∞		

LIFE-CYCLE COST CONSIDERATION WORKSHEET - BRIDGES

Bridge Subset (ex: State, NHS, Non-NHS): All Decked Bridges for Deterioration; NHS for Maintenance Info

To simplify the lifecycle cost analysis, assume the following condition categories from the NBI ratings:

- Good condition: NBI rating 7 to 9.
- Satisfactory condition: NBI rating 6.
- Fair condition: NBI rating 5.
- Poor condition: NBI rating 4 or less.

Deterioration Rates

Bridge Decks

- Suppose 100 bridge decks on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory (6) or worse condition, if no preservation action has been taken? 20-25 years
- Suppose 100 bridge decks on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 5-10 years (25-35 years total)
- Suppose 100 bridge decks on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 5-10 years (35-45 years total)
- Suppose 100 bridge decks on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? _____N/A__________________
  - Ranges due to ADT (>10K, 4-10K, <4K) and different bridge types
  - Includes bridges with decks; does not include culverts

Bridge Superstructures

- Suppose 100 bridge superstructures on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory (6) or worse condition, if no preservation action has been taken? 40-50 years
- Suppose 100 bridge superstructures on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 10-20 years (50-70 years)
- Suppose 100 bridge superstructures on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 10-30 years (60-100 years)
- Suppose 100 bridge superstructures on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? ____N/A_________________
  - Assumptions: Ranges due to sampling from 1960's built to present day and different superstructure types

Bridge Substructures

- Suppose 100 bridge substructures on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory or worse condition, if no preservation action has been taken? 40-50 years
- Suppose 100 bridge substructures on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 10-20 years (50-70 years)
- Suppose 100 bridge substructures on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 10-30 years(60-100 years)
- Suppose 100 bridge substructures on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? ________N/A_________________

Inspection Costs

What is the estimated average annual cost to collect and process bridge condition data so it can be used for reporting performance?

Average annual collection costs: $4.5 Million (includes culverts)

Average annual processing costs: $0.5 Million (includes culverts)

Treatment Costs

Five categories of repair are listed in tables B-1 through B-3, for bridge decks, superstructures, and substructures respectively. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor), and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. **Be sure to indicate the units used for your costs**.

Table B-1. Typical treatments and costs for bridge decks.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (Subset of Preventive Maintenance)	Flushing Deck, Joints, Drains	All Bridges with Decks	Same but slows deterioration rate	$100 - $1500/ Bridge	$500/ Bridge (Flushing entire bridge)
	Crack Sealing	Fair (5) or greater; dependent on programming and element condition state	Fair (5) or greater but improved element condition state	$2.5 -$4/LF of Crack	$3/ LF of Crack
	Deck Sealing			$0.2 - $4/ SF of deck	Highly dependent on material used
	Joint Sealing			$3 - $5/ LF of joint	$4/ LF of joint
	Rail Sealing			$3-$4/ LF of rail	$3.50/ LF of rail
Preventive Maintenance	Poured Joint Repair	Fair (5) or greater; dependent on programming and element condition state	Fair (5) or greater but improved element condition state	$50 – $200/ LF of joint	$100/ LF of Joint
	Expansion Joint Repair (Gland)			$100 – $400/ LF of joint	$250/ LF of joint
	Replace Joint			$375-$750/ LF of joint	Depends on joint type
	Relief Joint Repair			$5 - $50/ LF of joint	Depends on Repair
Minor Rehabilitation (Reactive Maintenance)	Deck Repair	Fair to Poor	Satisfactory	$20 - $55/ SF of repair area	$30/ SF of repair area
	Underdeck-Remove loose concrete/ repair	Fair to Poor	Same	Infrequent Reactive Maint	Infrequent Reactive Maint
	Polymer Overlay	Good to Satisfactory	Same	$7/ SF of deck	$7/ SF of deck
	LS Overlay	Poor	Satisfactory to Fair	$6-$8/ SF of deck	$7/ SF of deck

	Rail Repair	Good to Fair; dependent on element condition state	Same; improves element condition state	$100 - $165/ LF of rail repair area	$150/ LF of rail repair area
	Approach Panels	Dependent on element condition state	Improves element condition state	$10 - $20/ SF of repair area	$15/ SF of repair area
	Underpin (Infrequent Reactive Maint)	Poor	Poor; preserve public safety	Infrequent Reactive Maint	Infrequent Reactive Maint
Major Rehabilitation	Replace Railing	Good to Fair; dependent on element condition state	Same; improves element condition state	$150 - $300/ LF of rail	$200/ LF of rail
	Redeck	Poor	Good	$50 -$70/ SF of deck	$60/SF of deck
Reconstruction (Entire Bridge)	Reconstruction	Poor	Good	Variable	$145/ SF

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the bridge to deteriorate some more? *This analysis does not include routine maintenance, although routine maintenance, such as flushing, is performed annually to slow deterioration rates. Crack sealing is also performed to preserve the bridge deck and slow further deterioration.

- Good _100_%*
- Fair _70_%
- Poor _65_%

Table B-2. Typical treatments and costs for bridge superstructures.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (Subset of Preventive Maintenance)	Flushing Bearings, Beam Ends, Truss Members	All Bridges with Decks	Same but slows deterioration rate	$100 - $1500/ Bridge	$500/ Bridge (Flushing entire bridge)
	Clean and Lubricate Bearings	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	$800-$1100/ EACH Bearing	$1000/ EACH
Preventive Maintenance	Sealing/ Epoxy Injection	Good to Poor	Good to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Painting Beams	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	$12-$15/ SF of painted area	$13/ SF of painted area
Minor Rehabilitation (Reactive Maintenance)	Reset Bearings	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	$200-$500/ EACH Bearing	$300/ EACH Bearing
	Remove Loose Concrete	Fair to Poor; dependent on element condition state	Fair to Poor; improves element condition state	Infrequent Reactive Maint	Infrequent Reactive Maint
	Patching/ Gunite/Shot Crete	Fair to Poor; dependent on element condition state	Satisfactory to Fair; improves element condition state	$55 - $150/ SF of patch area	$100/ SF of patch area
	Arresting Fatigue Cracks	Poor	Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
Major Rehabilitation	Repair/ Replace Bearings	Poor	Good to Fair	$1600 - $2000/ EACH Bearing	$1750/ EACH Bearing
	Heat Straightening (*Infrequent reactive maint; typically in response to	Fair to Poor	Satisfactory	$6,500 - $9,000 per day + mob*	$6,500 per day + mob*

	bridge hits)				
	Repair Steel Elements (splice plates, stiffeners, etc)	Fair to Poor	Satisfactory to Fair	In response to bridge hits or older trusses (smaller subset of bridges)	In response to bridge hits or older trusses (smaller subset of bridges)
	Widening (Performed in response to increased traffic needs)	Poor	Good to Satisfactory	$300/ SF of deck (includes super, sub and deck)	$300/ SF of deck (includes super, sub and deck)
	Replace Concrete and Steel Elements	Poor	Good to Satisfactory	Infrequent Reactive Maint	Infrequent Reactive Maint
	Repair/ Replace Connections	Poor	Good to Fair	In response to critical findings or advanced section	In response to critical findings or advanced section
Reconstruction (Entire Bridge)	Reconstruction	Poor	Good	Variable	$145/ SF

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the bridge to deteriorate some more? *This analysis does not include routine maintenance, although routine maintenance, such as flushing, is performed annually to slow deterioration rates. Other routine maintenance, such as sealing, is performed as needed and can help slow deterioration.

- Good _100_%
- Fair _90_%
- Poor _75_%

Table B-3. Typical treatments and costs for bridge substructures.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (Subset of Preventive Maintenance)	Flushing bridge seats, pier caps	All Bridges with Decks	Same but slows deterioration rate	$100 - $1500/ Bridge	$500/ Bridge (Flushing entire bridge)
Preventive Maintenance	Sealing	Good to Poor	Good to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Painting	Good to Fair; dependent on element condition state	Good to Fair; improves element condition state	Infrequent Reactive Maint	Infrequent Reactive Maint
Reactive Maintenance	Debris Removal	All	Same, but prevents debris from causing more problems	Not applied directly to the substructure	Not applied directly to the substructure
Minor Rehabilitation (Reactive Maintenance)	Patching	Fair to Poor	Satisfactory to Fair	$55 - $150/ SF of patch area	$100/ SF of patch area
	Slope Paving Repair	Dependent on element condition state	Improves element condition state	$10 - $25/ SF of repair area	$20/ SF of repair area
	Riprap (Infrequent Reactive Maint)	Fair to Poor	Good to Satisfactory	$10,000 - $500,000	Depends on extent of project
Major Rehabilitation	Scour Repair	Fair to Poor	Good to Satisfactory	$50,000 - $500,000	Depends on extent of project
	Repair Steel Elements	Fair to Poor	Satisfactory to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Replace Steel Elements	Poor	Good to Satisfactory	Infrequent Reactive Maint	Infrequent Reactive Maint
	Replace Concrete Elements	Poor	Good to Satisfactory	Infrequent Reactive Maint	Infrequent Reactive Maint
Reconstruction (Entire Bridge)	Reconstruction	Poor	Good	Variable	$145/ SF

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the bridge to deteriorate some more? *This analysis does not include routine maintenance, although routine maintenance, such as flushing, is performed annually to slow deterioration rates. Other routine maintenance, such as sealing, is performed as needed and can help slow deterioration.

- Good _100_%
- Fair _90_%
- Poor _75_%

Overall Health Index

Please answer the following question to tell us the relative value you would place on each condition level, considering the effect on routine maintenance needs and on the quality of service given to the public, including risk. If Excellent condition is worth 100 points and Failed condition is worth zero points, how much should the other levels be worth?

- Good condition 100 points.
- Satisfactory condition 80 points.
- Fair condition 50 points.
- Poor condition 0 points.

LIFE-CYCLE COST CONSIDERATION WORKSHEET –
BRIDGE CULVERTS

Bridge Subset (ex: State, NHS, Non-NHS): Concrete Box Culverts > 10 FT

To simplify the lifecycle cost analysis, assume the following condition categories from the NBI ratings:

- Good condition: NBI rating 7 to 9.
- Satisfactory condition: NBI rating 6.
- Fair condition: NBI rating 5.
- Poor condition: NBI rating 4 or less.

Deterioration Rates

Culverts

- Suppose 100 culverts on this subset are currently in Good (7 or greater) condition. After how many years will 50 of them have deteriorated to Satisfactory (6) or worse condition, if no preservation action has been taken? 50 years
- Suppose 100 culverts on this subset are currently in Satisfactory (6) condition. After how many years will 50 of them have deteriorated to Fair (5) or worse condition, if no preservation action has been taken? 20 years (70 years total)
- Suppose 100 culverts on this subset are currently in Fair (5) condition. After how many years will 50 of them have deteriorated to Poor (4 or less) or worse condition, if no preservation action has been taken? 30 years (100 years total)
- Suppose 100 bridge decks on this subset are currently in Poor condition. After how many years will 50 of them have deteriorated to Failed condition, if no preservation action has been taken? _____N/A____________

Inspection Costs

What is the estimated average annual cost to collect and process bridge condition data so it can be used for reporting performance?

Average annual collection costs: $4.5 Million_(includes culverts)

Average annual processing costs: $0.5 Million_(includes culverts)

Treatment Costs

Five categories of repair are listed in tables B-4, for culverts. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor), and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. **Be sure to indicate the units used for your costs**.

Table B-4. Typical treatments and costs for culverts.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representativ e Cost
Routine Maintenance	None				
Preventive Maintenance	None				
Minor Rehabilitation (Reactive Maintenance)	Patching/ Minor Repairs	Fair to Poor	Satisfactory to Fair	$20 - $55/ SF of repair area	$30/ SF of repair area
	Debris Removal	All	Same, but prevents debris from causing more problems	Not applied directly to the culvert	Not applied directly to the culvert
	Scour Repair	Fair to Poor	Good to Satisfactory	$1000 - $10,000	Depends on extent of project
Major Rehabilitation	Wingwall/Headwall Rehab	Poor	Satisfactory to Fair	Infrequent Reactive Maint	Infrequent Reactive Maint
	Extend	Good to Fair	Good to Fair	Variable	$200,000
Reconstruction	Reconstruction	Poor	Good	Variable	$250,000

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the culvert to deteriorate some more?

- Good _100__%
- Fair _90__%
- Poor _55__%

LIFE-CYCLE COST CONSIDERATION WORKSHEET - HYDRAULICS

To simplify the lifecycle cost analysis, assume the following condition categories from the HydInfra ratings:

- Excellent (like new) condition: 1
- Fair condition: 2
- Poor condition: 3
- Very poor condition: 4

Deterioration Rates

Culverts

- Suppose 100 culverts are currently in Excellent condition. After how many years will 50 of them have deteriorated to Fair or worse condition, if no preservation action has been taken?
  - For Concrete Pipe: _____23________
  - For Metal Pipe: _______13_________
- Suppose 100 culverts are currently in Fair condition. After how many years will 50 of them have deteriorated to Poor or worse condition, if no preservation action has been taken?
  - For Concrete Pipe: _____33________
  - For Metal Pipe: ________16________
- Suppose 100 culverts are currently in Poor condition. After how many years will 50 of them have deteriorated to Very Poor condition, if no preservation action has been taken?
  - For Concrete Pipe: _____15________
  - For Metal Pipe: ________8________

Stormwater Tunnels

(Metro District has 7 stormwater tunnel systems that have been divided up into 50 segments. These tunnels were built between the early 1960's and late 1970's. The degradation of each tunnel is specific to the tunnel system. For example, the I-35W south tunnel is under a significant amount of pressure and it can go from good to fair to poor at a much higher rate than the other tunnels.)

Currently 32% of the 50 tunnel segments are rated fair, 42% are rated poor, and 26% are rated very poor.

Inspection Costs

What is the estimated average annual cost to collect and process culvert and tunnel condition data so it can be used for reporting performance?

Average annual collection costs for culverts: 7900 hours x $75/hr. (includes hourly rate $30 + 1.5 overhead rate) = $592,500 + $66,667 (consultant contract annualized over 3 years): Total $659,167 ($660K)

Average annual processing costs for culverts: 880 hours (same as above) = $66,000

Tunnel inspection costs (inspection and reports) are done via consultants. Typically $200,000 each year. The shared tunnels in the City of Minneapolis are on a 3-5 year inspection schedule.

Treatment Costs

Five categories of repair are listed in table H-1 and H-2 for culverts and tunnels, respectively. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor) and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. **Be sure to indicate the units used for your costs**.

Culverts

Table H-1. Typical treatments and costs for culverts.

Treatment Category	Representative Treatments	Typical Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance					
Preventive Maintenance					
Minor Rehabilitation		Poor or very poor	Fair		
	Reset ends				$2694.78 Each
	joint repair/Grout				$35.73/LF
	pave invert				$17.86/LF
Major Rehabilitation	Slipliner	Very poor	Excellent or Fair		$192.54
	CIPP				$142.62/LF
Replacement	Trench	Poor or very poor	Excellent		$71.91/LF + $28999.12/Ea
	Jack				$797.50/LF

Estimated repair costs based on 2010 Spreadsheet developed by Dave Solsrud/Dave Johnston of D8. Trench replacement cost includes the cost of the pavement replacement – will be much less expensive if done as part of a pavement project. Unit repair costs include the 10% contingency that was added in the spreadsheet estimation.

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the culvert to deteriorate some more?

- Excellent __100___%
- Fair ___98_____%
- Poor ___95_____%
- Very poor __88_____%

Stormwater Tunnels

Table H-2. Typical treatments and costs for stormwater tunnels.

Treatment Category	Representative Treatments	Typical Age or Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance	Remove sediment and debris	Not routinely done, only done when would cause plugging	Fair		
Preventive Maintenance	Seal cracks and infiltration points	Urgent	Fair		
Maintenance	Flush and grout voids, fill cracks	Urgent/poor	Good	Contractors can do $3.5 M per season	About $25M in needs that are known now
Major Maintenance	Repair broken crown/broken liner	Urgent/poor	Good		About $500,000 in needs that are known now
Replacement or Added Capacity	Replacement or Added Capacity	Never done this yet	Excellent		About $200M in needs that are known now

For each condition level, what percent of the time do you end up taking no action at all in a year and just allowing the tunnel to deteriorate some more?

- Excellent __100____%
- Fair ___100_____%
- Poor _99___%
- Very Poor ______%

Overall Health Index

Please answer the following question to tell us the relative value you would place on each condition level, considering the effect on routine maintenance needs and on the quality of service given to the public, including risk. If Excellent condition is worth 100 points and Failed condition is worth zero points, how much should the other levels be worth?

- Fair condition _____99______ points.
- Poor condition _____40______ points.
- Very Poor condition _____20______ points.

LIFE-CYCLE COST CONSIDERATION WORKSHEET – OTHER TRAFFIC STRUCTURES

Deterioration Rates

Tracked condition summaries and available research used to make assumptions on structure deterioration. See table below.

Summary of Current Condition

Overall Condition Rating	Description	SRF - Number of structures per rating	Structures that have Maintenance work done and/or planned construction work will move from 2,3,4,5 to 6	**7-2-13** Structures per condition rating	% of total	Structures with loose anchorages/nuts from condition ratings 2, 3, 4*	total after fixing nuts & moving to satisfactory	% of total after fixing nuts	Combined %	Proposed Performance Measure
2	Critical	143	**26**	117	6%	85	32	2.3%		
3	Serious	257	**53**	204	11%	92	112	7.9%	10.2%	10% or less
4	Poor	423	**81**	342	18%	237	105	7.4%	17.6%	20% or less
5	Fair	357	**70**	287	15%	0	287	20.3%		
6	Satisfactory	200	*49*	**430**	23%	0	**844**	59.6%		
7	Good	32	*2*	32	2%	0	32	2.3%		
8	Very Good	3	0	3	0%	0	3	0.2%		
			281	1415		414	1415			
			230 moved to 6							

CO Active Structures	1857	663	414
Retired per Metro	4		0.624434389
Not inspected	**438**		
Condition Total	1415		

For structures not inspected, the most reasonable assumption would be to go with the Good/Fair/Poor distribution observed for the structures inspected. This can be revised in the Asset Register

Poor	36%	62% (414) of these have loose anchorages/nuts
Fair	15%	
Good	25%	

Based on inspected structures:

Poor	249	17.6%	77		326	13.8%
Fair	287	20.3%	89		376	15.9%
Good	879	62.1%	272	510	1661	70.3%
Totals	**1415**		**438**		2363	

Modified percentages after structures statewide have been included. All remaining 510 structures are reported to be in 100% good condition.

]

Use the results of any of your inspections to record the types of repairs needed. Use table S-1 to record your results. If you have had more than 7 inspections, please add rows to the table. We will use the results to establish preliminary rates of deterioration.

Table S-1. Repairs required based on overhead sign structure inspections.

Inspection Cycle	Year	No. of Structures Inspected	No of Structures Requiring:					
			No Maintenance	Routine Maintenance	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation	Replacement
1	2006-07	718	159	504	NA	25	14	16
2	2010-11	856	591	231	NA	15	2	17
3	2012	86	0	0	NA	0	0	0
4								
5								
6								
7								

Inspection Costs

What is the estimated average annual cost to collect and process condition data on overhead sign structures and high mast light towers so it can be used for reporting performance?

- 2006-07 Metro consultant contract to inspect/report on 718 cantilevers $460,197; $640/structure
- 2010-11 Metro… " "… on 856 non-cantilever $1,007,967; $1170/structure
- 2012 District 6 worked 90 hours of inspection time including ultrasonic inspection of anchor rods on their cantilever signs. At an average rate of n$50.00/hour this works out to an approximate cost of $4500.00

Treatment Costs

Five categories of repair are listed in tables S-3 and S-4 for overhead sign structures and high mast light towers, respectively. For each of the categories, identify representative treatments that fit within that category, the typical condition range when these treatments are applied (e.g., Good, Fair, or Poor) and the condition after the treatment has been constructed. Also provide the typical price range for the treatments in that category and a cost that your Work Group considers to be the most representative cost within the price range. **Be sure to indicate the units used for your costs**.

We recognize that there are few preventive maintenance treatments that are applied to high mast tower light poles. Therefore, you may not have a response for each row in table S-4. As long as you provide us with information that tells us what types of repairs are needed, the typical age at which these repairs are made, and the average cost of the repairs, we will do our best to develop a life cycle treatment cycle for these structures.

Table S-3. Typical treatments and costs for overhead sign structures.

Treatment Category	Representative Treatments	Typical Age or Condition Level When Applied (e.g., Excellent, Good, Fair, or Poor)	Most Likely Condition After Treatment	Typical Cost Range	Most Representative Cost
Routine Maintenance (such as tightening bolts)	-Tighten base nuts -Remove Grout	Poor Poor	Fair Poor		(1) (2)
Preventive Maintenance (such as adding nuts/bolts to strengthen the structure and preserve life)	NA	NA	NA	NA	NA
Minor Rehabilitation (such as replacement of one or more minor structural components)	Re-grade footing, replace weld, remove catwalks/lighting, new mounting post	Poor	Fair - Good	$1700 - $6000	$3000
Major Rehabilitation (such as replacement of significant portions of the structure)	Replace foundation or replace truss or other elements	Poor	Good	$8,000-$30,000	$25,000
Replacement (including complete removal and replacement of the structure)	Replacement	40 years	New	$10,000-$110,000	(3)

(1) Our crews tightened nuts on 300 overhead structures: 1015 hours @ $50/person = $50,750 and $6800 Equipment Cost = $57550/300 = $200/structure* and $40,000 for wrench. * Does not include traffic control costs

(2) Mendota removed 15 signs with grout in their area; 276 hours @ $50/person = $14,000 and $1400 equipment cost = $15,400/15 signs = $1000/sign*. *Does not include traffic control costs.

(3) Metro assumes a scoping replacement cost of $10K for bridge mounts, $60K for scoping of cantilever replacement, and $110K for scoping of sign bridges. Contracts (does not include mobilization or traffic control: usually assumed to be 20% of total project cost):

   (4) 2009 – Minor Rehab = $6,000 (1 structure); Major rehab $8000 (1 structure)
   2010 – Minor Rehab = $1,700 (1); Major rehab $300,000 (13) $30K average
   2011 – Major $340,000 (14) $24K average
   2012 – Major $270,000 (18) $15K average

LIFE-CYCLE COST ANALYSES
MODELING EXAMPLES
(INPUTS AND RESULTS)

PAVEMENT MODEL*

INPUTS

*The Other Traffic Structures (Overhead Sign Structures and High-Mast Tower Lighting Structures) model included the same format spreadsheets.

INPUT WORKSHEET

1. Economic Variables

Value of Time for Passenger Cars ($/hour)	$2.00
Value of Time for Single Unit Trucks ($/hour)	$2.00
Value of Time for Combination Trucks ($/hour)	$2.00

2. Analysis Options

Include User Costs in Analysis	No
Include User Cost Remaining Life Value	Yes
Use Differential User Costs	Yes
User Cost Computation Method	Calculated
Include Agency Cost Remaining Life Value	Yes
Traffic Direction	Both
Analysis Period (Years)	50
Beginning of Analysis Period	2013
Discount Rate (%)	2.2
Number of Alternatives	5

3. Project Details

State Route	
Project Name	MnDOT LCCA: AC Pavements - Desired
Region	
County	
Analyzed By	
Mileposts	
Begin	
End	
Length of Project (miles)	0.00
Comments	

4. Traffic Data

AADT Construction Year (total for both directions)	2,000
Cars as Percentage of AADT (%)	96.0
Single Unit Trucks as Percentage of AADT (%)	2.0
Combination Trucks as Percentage of AADT (%)	2.0
Annual Growth Rate of Traffic (%)	2.0
Speed Limit Under Normal Operating Conditions (mph)	55
No of Lanes in Each Direction During Normal Conditions	1
Free Flow Capacity (vphpl)	2157
Rural or Urban Hourly Traffic Distribution	Rural
Queue Dissipation Capacity (vphpl)	200
Maximum AADT (total for both directions)	2,577
Maximum Queue Length (miles)	1.0

5. Construction

Alternative 1 — Flexible Pavements - Desired Srategy
Number of Activities — 10

	Activity 1	Activity 2	Activity 3
Activity name	Initial Construction	Crack Treatment	Surface Treatment
Agency Construction Cost ($1000)	#NAME?	#NAME?	#NAME?
User Work Zone Costs ($1000)			
Work Zone Duration (days)	5	5	5
No of Lanes Open in Each Direction During Work Zone	1	1	1
Activity Service Life (years)	#NAME?	#NAME?	#NAME?
Activity Structural Life (years)	20.0	0.0	8.0
Maintenance Frequency (years)	3	3	3
Agency Maintenance Cost ($1000)	2.38	2.38	2.38
Work Zone Length (miles)	1.00	1.00	1.00
Work Zone Speed Limit (mph)	55	55	55
Work Zone Capacity (vphpl)	200	200	200
Traffic Hourly Distribution	Week Day 1	Week Day 1	Week Day 1

Alternative 2 — Flexible Pavements - Typical Strategy
Number of Activities — 11

	Activity 1	Activity 2	Activity 3
Activity name	Initial Construction	Crack Treatment	Surface Treatment
Agency Construction Cost ($1000)	#NAME?	#NAME?	#NAME?
User Work Zone Costs ($1000)			
Work Zone Duration (days)	5	5	5
No of Lanes Open in Each Direction During Work Zone	1	1	1
Activity Service Life (years)	#NAME?	#NAME?	#NAME?
Activity Structural Life (years)	15.0	0.0	9.0
Maintenance Frequency (years)	3	3	3
Agency Maintenance Cost ($1000)	2.38	2.38	2.38
Work Zone Length (miles)	1.00	1.00	1.00
Work Zone Speed Limit (mph)	55	55	55
Work Zone Capacity (vphpl)	200	200	200
Traffic Hourly Distribution	Week Day 1	Week Day 1	Week Day 1

Alternative 3 — Flexible Pavement - Worst First
Number of Activities — 3

	Activity 1	Activity 2	Activity 3
Activity name	Initial Construction	Reconstruction - 1	Reconstruction - 2
Agency Construction Cost ($1000)	#NAME?	#NAME?	#NAME?
User Work Zone Costs ($1000)			
Work Zone Duration (days)	5	5	5
No of Lanes Open in Each Direction During Work Zone	1	1	1
Activity Service Life (years)	#NAME?	#NAME?	#NAME?
Activity Structural Life (years)	20.0	20.0	20.0
Maintenance Frequency (years)	3	3	3
Agency Maintenance Cost ($1000)	2.38	2.38	2.38
Work Zone Length (miles)	1.00	1.00	1.00
Work Zone Speed Limit (mph)	55	55	55
Work Zone Capacity (vphpl)	200	200	200
Traffic Hourly Distribution	Week Day 1	Week Day 1	Week Day 1

For each activity of each alternative:

Time of Day of Lane Closures (use whole numbers based on a 24-hour clock)

Inbound	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

Outbound	Start	End
First period of lane closure		
Second period of lane closure		
Third period of lane closure		

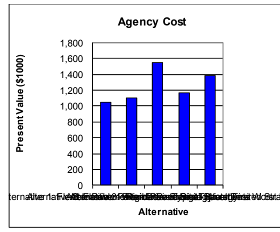
DETERMINISTIC RESULTS

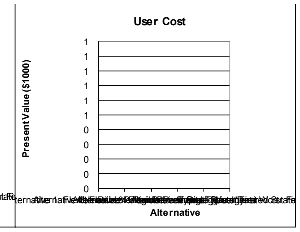
Total Cost	Alternative 1: Flexible Pavements - Desired Srategy		Alternative 2: Flexible Pavements - Typical Strategy		Alternative 3: Flexible Pavement - Worst First		Alternative 4: Rigid Pavements Typical/Desired Strategy		Alternative 5: Rigid Pavements Worst First	
	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Undiscounted Sum	*$1,233.07*	*$0.00*	*$1,302.42*	*$0.00*	*$2,052.37*	*$0.00*	*$1,305.62*	*$0.00*	*$1,656.11*	*$0.00*
Present Value	**$1,046.58**	**$0.00**	**$1,099.92**	**$0.00**	**$1,552.06**	**$0.00**	**$1,163.60**	**$0.00**	**$1,388.59**	**$0.00**
EUAC	$34.72	$0.00	$36.49	$0.00	$51.49	$0.00	$38.60	$0.00	$46.07	$0.00

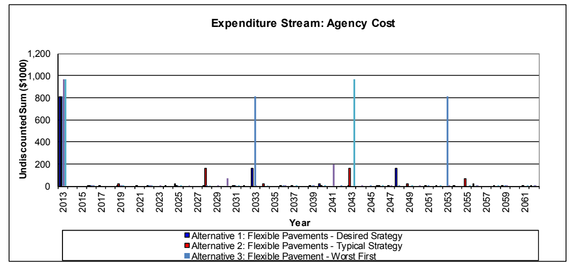
Lowest Present Value Agency Cost	Alternative 1: Flexible Pavements - Desired Srategy
Lowest Present Value User Cost	Alternative 1: Flexible Pavements - Desired Srategy

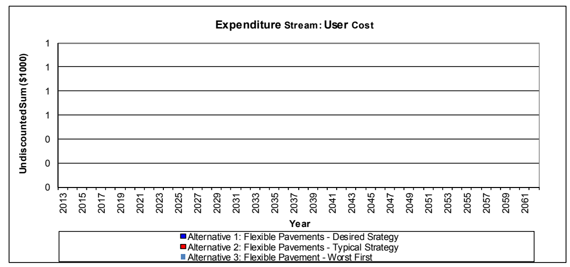
Expenditure Stream

Year	ve 1: Flexible Pavements - Desire		ve 2: Flexible Pavements - Typica		ative 3: Flexible Pavement - Wors		4: Rigid Pavements Typical/Desir		native 5: Rigid Pavements Worst	
	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
2013	$806.67		$806.67		$806.67		$966.67		$966.67	
2014										
2015										
2016	$2.38		$2.38		$2.38		$2.38		$3.00	
2017			$6.33							
2018										
2019	$2.38		$18.33		$2.38		$2.38		$3.00	
2020										
2021	$6.33									
2022			$2.38		$2.38		$2.38		$3.00	
2023							$10.00			
2024	$2.38									
2025	$18.33		$2.38		$2.38				$3.00	
2026							$2.38			
2027										
2028	$2.38		$158.33		$2.38				$3.00	
2029							$2.38			
2030							$71.67			
2031	$2.38		$3.48		$2.38				$3.00	
2032			$6.33							
2033	$158.33				$806.67		$3.48			
2034			$18.33						$3.00	
2035										
2036	$6.33				$2.38		$3.48			
2037			$3.48						$3.00	
2038										
2039	$3.48				$2.38		$3.48			
2040	$18.33		$3.48						$3.00	
2041							$198.33			
2042					$2.38					
2043	$3.48		$158.33						$966.67	
2044							$5.23			
2045					$2.38					
2046	$3.48		$3.48						$3.00	
2047			$6.33				$5.23			
2048	$158.33				$2.38					
2049			$18.33						$3.00	
2050							$5.23			
2051	$6.33				$2.38					
2052			$5.23						$3.00	
2053					$806.67		$5.23			
2054	$5.23									
2055			$68.33						$3.00	
2056	$18.33				$2.38		$5.23			
2057										
2058			$5.23						$3.00	
2059	$5.23				$2.38		$5.23			
2060										
2061			$5.23						$3.00	
2062	$5.23				$2.38		$5.23			
2063	($2.29)				($403.33)				($322.22)	



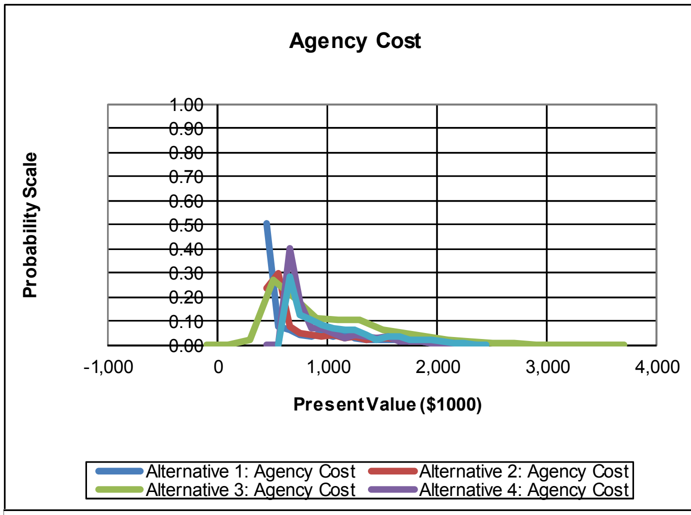


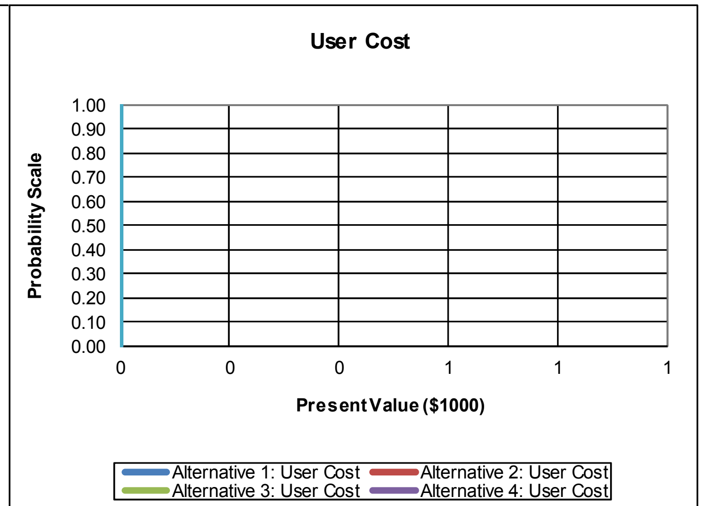


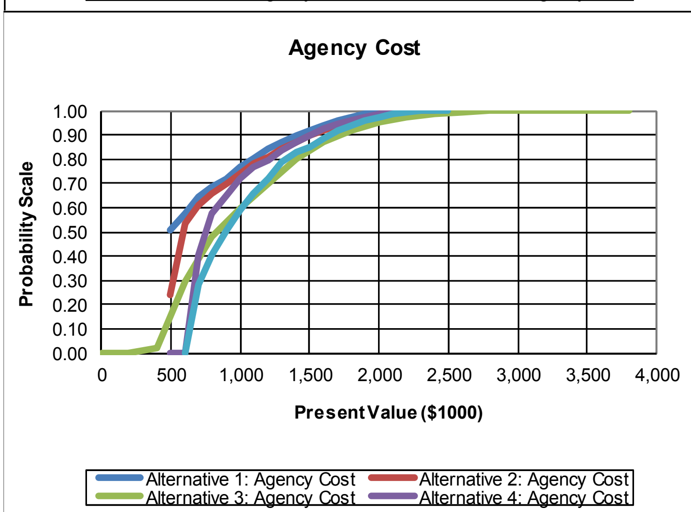


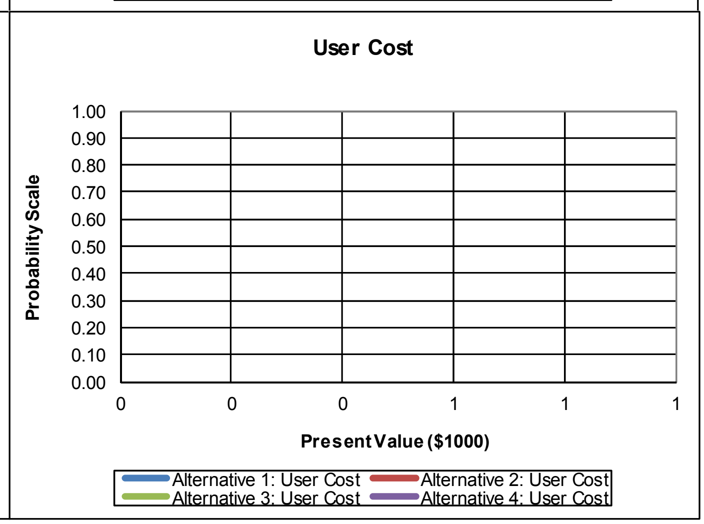
PROBABLISTIC RESULTS

Total Cost										
	Alternative 1: Flexible Pavements - Desired		**Alternative 2: Flexible Pavements - Typical**		**Alternative 3: Flexible Pavement - Worst First**		**Alternative 4: Rigid Pavements**		**Alternative 5: Rigid Pavements Worst First**	
Total Cost (Present Value)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Mean	$741.81	$0.00	$806.63	$0.00	$979.54	$0.00	$923.66	$0.00	$1,025.66	$0.00
Standard Deviation	$414.33	$0.00	$427.91	$0.00	$518.40	$0.00	$359.33	$0.00	$395.24	$0.00
Minimum	$408.66	$0.00	$455.56	$0.00	$371.45	$0.00	$611.75	$0.00	$612.54	$0.00
Maximum	$2,164.02	$0.00	$2,215.59	$0.00	$3,067.49	$0.00	$2,187.16	$0.00	$2,394.71	$0.00







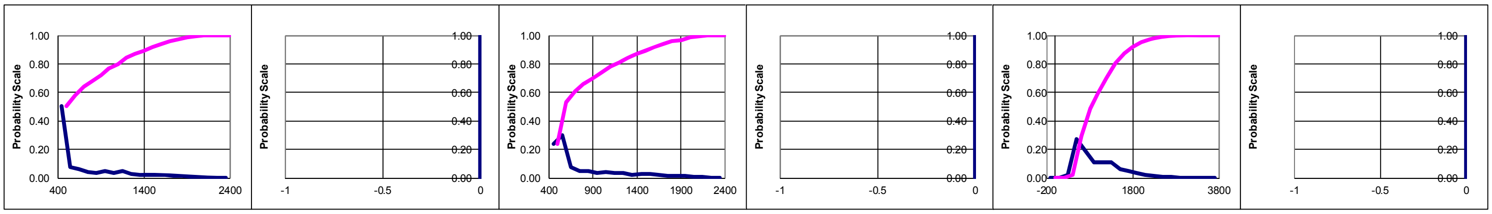


OUTPUT DISTRIBUTIONS

Alternative 1: Agency Cost				Alternative 1: User Cost			
Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.	Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.
500	450	0.50	0.50	0	0	1.00	1.00
600	550	0.07	0.58	0	0	0.00	1.00
700	650	0.06	0.64	0	0	0.00	1.00
800	750	0.04	0.68	0	0	0.00	1.00
900	850	0.04	0.72	0	0	0.00	1.00
1000	950	0.05	0.77	0	0	0.00	1.00
1100	1050	0.03	0.80	0	0	0.00	1.00
1200	1150	0.05	0.84	0	0	0.00	1.00
1300	1250	0.03	0.87	0	0	0.00	1.00
1400	1350	0.02	0.89	0	0	0.00	1.00
1500	1450	0.02	0.92	0	0	0.00	1.00
1600	1550	0.02	0.94	0	0	0.00	1.00
1700	1650	0.02	0.96	0	0	0.00	1.00
1800	1750	0.01	0.97	0	0	0.00	1.00
1900	1850	0.01	0.98	0	0	0.00	1.00
2000	1950	0.01	0.99	0	0	0.00	1.00
2100	2050	0.01	1.00	0	0	0.00	1.00
2200	2150	0.00	1.00	0	0	0.00	1.00
2300	2250	0.00	1.00	0	0	0.00	1.00
2400	2350	0.00	1.00	0	0	0.00	1.00

Alternative 2: Agency Cost				Alternative 2: User Cost			
Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.	Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.
500	450	0.24	0.24	0	0	1.00	1.00
600	550	0.30	0.53	0	0	0.00	1.00
700	650	0.07	0.61	0	0	0.00	1.00
800	750	0.05	0.66	0	0	0.00	1.00
900	850	0.04	0.70	0	0	0.00	1.00
1000	950	0.04	0.74	0	0	0.00	1.00
1100	1050	0.04	0.78	0	0	0.00	1.00
1200	1150	0.03	0.81	0	0	0.00	1.00
1300	1250	0.03	0.85	0	0	0.00	1.00
1400	1350	0.02	0.87	0	0	0.00	1.00
1500	1450	0.03	0.89	0	0	0.00	1.00
1600	1550	0.03	0.92	0	0	0.00	1.00
1700	1650	0.02	0.94	0	0	0.00	1.00
1800	1750	0.02	0.96	0	0	0.00	1.00
1900	1850	0.01	0.97	0	0	0.00	1.00
2000	1950	0.02	0.98	0	0	0.00	1.00
2100	2050	0.01	0.99	0	0	0.00	1.00
2200	2150	0.01	1.00	0	0	0.00	1.00
2300	2250	0.00	1.00	0	0	0.00	1.00
2400	2350	0.00	1.00	0	0	0.00	1.00

Alternative 3: Agency Cost				Alternative 3: User Cost			
Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.	Bin	Mid Point	Rel. Freq.	Cum. Rel. Freq.
0	-100	0.00	0.00	0	0	1.00	1.00
200	100	0.00	0.00	0	0	0.00	1.00
400	300	0.02	0.02	0	0	0.00	1.00
600	500	0.27	0.29	0	0	0.00	1.00
800	700	0.19	0.48	0	0	0.00	1.00
1000	900	0.11	0.59	0	0	0.00	1.00
1200	1100	0.11	0.70	0	0	0.00	1.00
1400	1300	0.11	0.80	0	0	0.00	1.00
1600	1500	0.06	0.87	0	0	0.00	1.00
1800	1700	0.05	0.92	0	0	0.00	1.00
2000	1900	0.04	0.95	0	0	0.00	1.00
2200	2100	0.02	0.97	0	0	0.00	1.00
2400	2300	0.01	0.99	0	0	0.00	1.00
2600	2500	0.01	0.99	0	0	0.00	1.00
2800	2700	0.00	1.00	0	0	0.00	1.00
3000	2900	0.00	1.00	0	0	0.00	1.00
3200	3100	0.00	1.00	0	0	0.00	1.00
3400	3300	0.00	1.00	0	0	0.00	1.00
3600	3500	0.00	1.00	0	0	0.00	1.00
3800	3700	0.00	1.00	0	0	0.00	1.00



EXTREME TAIL ANALAYSIS

Input Variable		Alternative 1: Agency Cost				Alternative 1: User Cost			
Name	Probability Function	5%	10%	90%	95%	5%	10%	90%	95%
Alternative 1: Activity 1: Agency (	LCCATRIANG(210,210,2000)	-0.01	-0.01	2.89	3.31	-0.01	-0.01	2.89	3.31
Alternative 2: Activity 1: Agency (	LCCATRIANG(210,210,2000)	0.17	0.07	0.08	0.07	0.17	0.07	0.08	0.07
Alternative 3: Activity 1: Agency (	LCCATRIANG(210,210,2000)	0.09	0.01	0.20	0.37	0.09	0.01	0.20	0.37
Alternative 4: Activity 1: Agency (	LCCATRIANG(450,450,2000)	0.00	0.00	0.01	0.25	0.00	0.00	0.01	0.25
Alternative 5: Activity 1: Agency (	LCCATRIANG(450,450,2000)	-0.01	0.18	0.01	-0.01	-0.01	0.18	0.01	-0.01
Alternative 1: Activity 1: Service L	LCCATRIANG(6,8,10)	1.08	0.82	0.07	0.13	1.08	0.82	0.07	0.13
Alternative 2: Activity 1: Service L	LCCATRIANG(3,4,5)	-0.12	-0.09	-0.16	-0.16	-0.12	-0.09	-0.16	-0.16
Alternative 3: Activity 1: Service L	LCCATRIANG(15,20,25)	-0.05	-0.09	-0.21	-0.13	-0.05	-0.09	-0.21	-0.13
Alternative 4: Activity 1: Service L	LCCATRIANG(8,10,12)	-0.08	-0.06	0.02	0.15	-0.08	-0.06	0.02	0.15
Alternative 5: Activity 1: Service L	LCCATRIANG(25,30,35)	0.04	-0.04	0.09	0.00	0.04	-0.04	0.09	0.00
Alternative 1: Activity 2: Agency (	LCCATRIANG(3,6,10)	-0.04	-0.12	0.00	-0.04	-0.04	-0.12	0.00	-0.04
Alternative 2: Activity 2: Agency (	LCCATRIANG(3,6,10)	-0.20	-0.08	0.11	0.11	-0.20	-0.08	0.11	0.11
Alternative 3: Activity 2: Agency (	LCCATRIANG(210,210,2000)	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.18
Alternative 4: Activity 2: Agency (	LCCATRIANG(5,10,15)	0.05	0.12	0.10	-0.04	0.05	0.12	0.10	-0.04
Alternative 5: Activity 2: Agency (	LCCATRIANG(450,450,2000)	-0.06	-0.06	0.14	0.13	-0.06	-0.06	0.14	0.13
Alternative 1: Activity 2: Service L	LCCATRIANG(3,4,5)	0.44	0.39	-0.01	-0.17	0.44	0.39	-0.01	-0.17
Alternative 2: Activity 2: Service L	LCCATRIANG(1,2,3)	-0.11	0.00	0.07	-0.08	-0.11	0.00	0.07	-0.08
Alternative 3: Activity 2: Service L	LCCATRIANG(15,20,25)	-0.07	0.08	-0.02	-0.02	-0.07	0.08	-0.02	-0.02
Alternative 4: Activity 2: Service L	LCCATRIANG(6,6,8)	0.57	0.14	0.03	0.02	0.57	0.14	0.03	0.02
Alternative 5: Activity 2: Service L	LCCATRIANG(25,30,35)	0.30	0.08	-0.28	-0.46	0.30	0.08	-0.28	-0.46

SIMULATION OUTPUT

Statistics	LCCA Output: Alternative 1: Agency Cost	LCCA Output: Alternative 1: User Cost	LCCA Output :Alternative 2: Agency Cost	LCCA Output :Alternative 2: User Cost	LCCA Output :Alternative 3: Agency Cost	LCCA Outpu t:Alternative 3: User Cost
Probability Function						
Minimum	$408.66	$0.00	$455.56	$0.00	$371.45	$0.00
Maximum	$2,164.02	$0.00	$2,215.59	$0.00	$3,067.49	$0.00
Mean	$741.81	$0.00	$806.63	$0.00	$979.54	$0.00
Median	$495.19	$0.00	$557.84	$0.00	$842.96	$0.00
Standard Deviation	$414.33	$0.00	$427.91	$0.00	$518.40	$0.00
Percentile (5%)	$425.12	$0.00	$482.63	$0.00	$412.15	$0.00
Percentile (10%)	$431.22	$0.00	$488.23	$0.00	$428.70	$0.00
Percentile (90%)	$1,412.54	$0.00	$1,521.90	$0.00	$1,733.18	$0.00
Percentile (95%)	$1,647.93	$0.00	$1,734.60	$0.00	$1,980.51	$0.00
Iteration 1	$608.58	$0.00	$2,215.59	$0.00	$662.11	$0.00
2	$1,327.23	$0.00	$877.60	$0.00	$540.96	$0.00
3	$924.45	$0.00	$590.15	$0.00	$1,012.94	$0.00
4	$413.46	$0.00	$720.77	$0.00	$816.52	$0.00
5	$476.86	$0.00	$1,783.80	$0.00	$703.60	$0.00
6	$1,147.69	$0.00	$487.28	$0.00	$1,662.16	$0.00
7	$451.26	$0.00	$562.08	$0.00	$1,485.15	$0.00
8	$1,789.60	$0.00	$1,542.13	$0.00	$812.27	$0.00
9	$797.38	$0.00	$475.61	$0.00	$595.76	$0.00
10	$1,540.23	$0.00	$560.27	$0.00	$632.49	$0.00

PAVEMENT LCCA RESULTS

Deterministic Analysis			
	FDR/Reconstruct	Mill OL	Worst-First
Undiscounted Sum	$766,261	$984,441	$1,988,023
Net Present Value (NPV)	$386,180	$409,698	$976,317
Equivalent Uniform Annual Cost (EUAC)	$10,864	$11,526	$27,466
% of initial cost	111%	142%	287%
Probabilistic Analysis			
Mean Net Present value (NPV)	$375,668	$392,754	$635,313
Standard Deviation	$34,609	$33,862	$314,516

Note: All costs in $/lane-mi
Initial costs not included in analysis

BRIDGE MODEL*

BRIDGE DECK INPUTS

Life cycle cost inputs - Bridge decks

General	Good	Satis	Fair	Poor	Total			
Number of bridges	1029	283	74	15	1401	Deck area	26.203	million sq.ft
Health index weight	100	80	50	0		Joint quantity	535398	LF
Discount rate	2.2%					Rail quantity	1118213	LF

MnDOT Modified

Comments:
1. Modified Bridge Counts, Deck Area, Joint Qty and Rail Qty based on Thomas' email from 8/14
2. Added Crack Sealing to Routine Maintenance
3. Added Gland Repair/Replace to Corrective Action
4. Added Redeck to Rehab/Replacement
5. Modified percentages based on maintenance data and typical frequencies
6. Modified deck repair unit/bridge based on bridge maintenance supervisor input

Deterioration model - without preservation

	Years	Good	Satis	Fair	Poor
Good	18	96.2%	3.8%	0.0%	0.0%
Satis	5		87.1%	12.9%	0.0%
Fair	5			87.1%	12.9%
Poor	--				100%

Deterioration model - with preservation

	Years	Good	Satis	Fair	Poor
Good	22.5	97.0%	3.0%	0.0%	0.0%
Satis	7.5		91.2%	8.8%	0.0%
Fair	7.5			91.2%	8.8%
Poor	--				100%

Routine maintenance					% bridges acted upon in a year				Real ✓								
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor	Totals			
Inspection	Bridge	1111	0	0.0	60%	60%	60%	60%	0.0	617.4	169.8	44.4	9	840.6	4500 state bridges over 10 ft (including culverts)		
Flushing	Bridge	500	0	0.0	75%	75%	75%	75%	0.0	771.75	212.25	55.5	11.25	1050.8	350.25	560.4	375.5
Joint sealing	LF	4	382	1.5	13%	13%	13%		0.3	128.63	35.375	9.25	0	173.25	175.13	12.50%	(8 year cycle)
Deck sealing	SF	2	18703	37.4	14%	14%	14%		7.3	144.06	39.62	10.36	0	194.04	200.34	14.30%	(7 year cycle
Crack Sealing	LF	3	500	1.5	20%	20%	20%		0.4	205.8	56.6	14.8	0	277.2	280.2	20%	(5 year cycle)
Annual cost per bridge - no preservation ($k)					0.0	0.0	0.0	0.0	0.0								
Annual cost per bridge - preservation scenario ($k)					5.7	5.7	5.7	0.0	7.9								

Corrective action					% bridges acted upon in a year				Real ✓	Percent improved											
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Effect	Good	Satis	Fair	Poor	Satis	Fair	Poor	Totals	From Maint Total		0.3111
Joint repair (patch)	SF	100	382	38.2		1%	2%		0.2	0.3	0.0%	0.3%	0.6%	0.0%	2.83	1.48	0	4.31	11.75	3.525	
Gland Repair/Replace	LF	250	382			1%	5%		0.0	0.5	0.0%	0.5%	2.5%	0.0%	2.83	3.7	0	6.53		0	
Deck repair	SF	30	561	16.8		2%	35%	15%	0.6	0.5	0.0%	1.0%	17.5%	7.5%	5.66	25.9	2.25	33.81	130	39	0.0241
Overlay	Each	7	18703	130.9		0%	5%	2%	0.5	0.8	0.0%	0.0%	4.0%	1.6%	0	3.7	0.3	4	7	2.1	
Rail repair/replace	Bridge	160	798	127.7		1%	5%		0.8	0.2	0.0%	0.2%	1.0%	0.0%	2.83	3.7	0	6.53	22.5	6.75	
Total percent acted upon					0%	5%	52%	17%							14.15	38.48	2.55	55.18			
Annual cost per bridge ($k)					0.0	2.0	19.6	5.1	2.1		0.0%	2.0%	25.6%	9.1%							
Approximate interval (years)									25.4												

Rehab/replacement					% bridges acted upon in a year				Real ✓	Resulting condition			
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor
Redeck	SF	60	18703	1122.2				5%	0.8	100%			
Replace Structure	SF	145	0	0.0				20%	0.0	100%			
Total percent acted upon					0%	0%	0%	25%					
Annual cost per bridge ($k)					0.0	0.0	0.0	56.1	0.8	100.0%	0.0%		
								42%		0.0222			
										0.0107			

*The Hydraulic Infrastructure (highway culverts and deep stormwater tunnels) model included the same format spreadsheets.

BRIDGE SUPERSTRUCTURE INPUTS

Life cycle cost inputs - Bridge superstructures

General	Good	Satis	Fair	Poor	Total			
Number of bridges	1047	272	65	17	1401	Deck area	26.116	million sq.ft
Health index weight	100	80	50	0		Bearing count	37,266	
Discount rate	2.2%							

MnDOT Modified

Comments:
1. Modified Bridge Counts, Deck Area, Joint Qty and Rail Qty based on Thomas' email from 8/14
2. Added Full Painting to list of corrective action
3. Modified percentages based on maintenance data, contract data and typical frequencies
4. Modified Painting and Patching Unit/Br based on bridge maintenance supervisor input

Deterioration model - without preservation	Years	Good	Satis	Fair	Poor
Good	30	97.7%	2.3%	0.0%	0.0%
Satis	10		93.3%	6.7%	0.0%
Fair	10			93.3%	6.7%
Poor	--				100%

Deterioration model - with preservation	Years	Good	Satis	Fair	Poor
Good	45	98.5%	1.5%	0.0%	0.0%
Satis	15		95.5%	4.5%	0.0%
Fair	20			96.6%	3.4%
Poor	--				100%

Routine maintenance					% bridges acted upon in a year				Real ✓								
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satisfactory	Fair	Poor	Totals			
Inspection	Bridge	1111	1	1.1	60%	60%	60%	60%	0.9	628.2	163.2	39	10.2	840.6	602-752		
Flushing	Bridge	500	1	0.5	75%	75%	75%	75%	0.5	785.25	204	48.75	12.75	1050.8			
Lube bearings	Each	1000	27	26.6	0%	0%	0%		0.0	1.047	0.544	0	0	1.591		6	1.8
Annual cost per bridge - no preservation ($k)					0.7	0.7	0.7	0.7	0.9								2%
Annual cost per bridge - preservation scenario ($k)					1.1	1.1	1.0	1.0	1.5								

Corrective action					% bridges acted upon in a year				Real ✓	Percent improved											
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Effect	Good	Satis	Fair	Poor	Good	Satis	Fair	Poor	Totals	From Maint Data	
Spot Painting	SF	13	1500	19.5		2%	5%		0.2	0.7	0.0%	1.4%	3.5%	0.0%	0	5.44	3.25	0	8.69	33	9.9
Full Painting	SF	14	27961	377.5		3%	5%		4.3	1	0.0%	3.0%	5.0%	0.0%	0	8.16	3.25	0	11.41	13	
Patching	SF	100	300	30.0		1%	3%	5%	0.2	0.5	0.0%	0.5%	1.5%	2.5%	0	2.72	1.95	0.85	5.52	16	4.8
Repair/repl bearings	Each	1750	27	46.5				5%	0.0	0.6	0.0%	0.0%	0.0%	3.0%	0	0	0	0.85	0.85	3	0.9
Repair steel	Bridge	50000	1	50.0			2%	5%	0.1	0.3	0.0%	0.0%	0.6%	1.5%	0	0	1.3	0.85	2.15	7	2.1
Total percent acted upon					0%	6%	15%	15%							0	16.32	9.75	2.55	28.62		
Annual cost per bridge ($k)					0.0	12.0	21.7	6.3	4.8		0.0%	4.9%	10.6%	7.0%					0.0204		
Approximate interval (years)									49.0												

Rehab/replacement					% bridges acted upon in a year				Real ✓	Resulting condition				
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor	Poor
Replace elements	Bridge	100000	1	100.0				1%	0.0	90%	10%			0.085
Replace structure	SF	145	18641	2702.9				20%	9.2	100%				3.4
Total percent acted upon					0%	0%	0%	21%						
Annual cost per bridge ($k)					0.0	0.0	0.0	541.1	9.2	99.8%	0.2%			
								36%						

Life cycle cost inputs - Bridge substructures

General	Good	Satis	Fair	Poor	Total			
Number of bridges	1061	271	62	9	1403	Deck area	26.222	million sq.ft
Health index weight	100	80	50	0				
Discount rate	2.2%							

MnDOT Modified

Comments:
1. Modified Bridge Counts, Deck Area, Joint Qty and Rail Qty based on Thomas' email from 8/14
2. Modified action title "Scour repair" to "Erosion/scour repair". Modified cost because there may be smaller projects involved.
3. Modified percentages based on maintenance data, contract data and typical frequencies
4. Modified patching and slope paving repair unit/br based on bridge

Deterioration model - without preservation					
	Years	Good	Satis	Fair	Poor
Good	30	97.7%	2.3%	0.0%	0.0%
Satis	10		93.3%	6.7%	0.0%
Fair	10			93.3%	6.7%
Poor	--				100%

Deterioration model - with preservation					
	Years	Good	Satis	Fair	Poor
Good	45	98.5%	1.5%	0.0%	0.0%
Satis	15		95.5%	4.5%	0.0%
Fair	20			96.6%	3.4%
Poor	--				100%

Routine maintenance					% bridges acted upon in a year				Real ✓
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr
Inspection	Bridge	1111	0	0.0	60%	60%	60%	60%	0.0
Flushing	Bridge	500	0	0.0	75%	75%	75%	75%	0.0
Not used	Each	0	1	0.0					0.0
Annual cost per bridge - no preservation ($k)					0.0	0.0	0.0	0.0	0.0
Annual cost per bridge - preservation scenario ($k)					0.0	0.0	0.0	0.0	0.0

Corrective action					% bridges acted upon in a year				Real ✓	Percent improved											
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Effect	Good	Satis	Fair	Poor	Good	Satis	Fair	Poor	Totals	From Maintenance Data	
Patching	SF	100	561	56.1			10%	15%	0.4	0.5	0.0%	0.0%	5.0%	7.5%	0	0	6.2	1.35	7.55	29	8.7
Slope paving repair	SF	20	1308	26.2		1%	1%		0.1	0.2	0.0%	0.1%	0.2%	0.0%	0	1.355	0.62	0	1.975	5	1.5
Erosion/Scour Repair	Each	25000	1	25.0			5%	5%	0.1	0.1	0.0%	0.0%	0.5%	0.5%	0	0	3.1	0.45	3.55	15	4.5
Not used	Each	0	1	0.0					0.0		0.0%	0.0%	0.0%	0.0%	0	0	0	0	0		
Total percent acted upon					0%	1%	16%	20%							0	1.355	9.92	1.8	13.075		
Annual cost per bridge ($k)					0.0	0.1	7.1	9.7	0.6		0.0%	0.1%	5.7%	8.0%							
Approximate interval (years)									107.3												

Rehab/replacement					% bridges acted upon in a year				Real ✓	Resulting condition				
Treatment	Units	$/unit	Unit/br	$k/br	Good	Satis	Fair	Poor	$M/yr	Good	Satis	Fair	Poor	Poor
Replace elements	Bridge	100000	1	100.0				1%	0.0	90%	10%			0.045
Replace structure	SF	145	0	0.0				20%	0.0	100%				1.8
Total percent acted upon					0%	0%	0%	21%						
Annual cost per bridge ($k)					0.0	0.0	0.0	0.5	0.0	99.8%	0.2%			
								41%						

BRIDGE DECK PROJECTIONS (20 OF 200 YEAR ANALYSIS)

Forecast condition and cost - Bridge decks

	Pure deterioration - no maint					Pure deterioration - routine maint					Worst-first scenario					($M)	Worst-first - typical bridge					Preservation scenario					($M)	Preservation - typical bridge				
Year	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health
0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.00	0.00	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	8.02	8.02	1.000	0.000	0.000	0.000	100.0
1	0.962	0.038	0.000	0.000	99.24	0.970	0.030	0.000	0.000	99.39	0.962	0.038	0.000	0.000	0.00	0.00	0.962	0.038	0.000	0.000	99.24	0.970	0.030	0.000	0.000	8.11	7.94	0.970	0.030	0.000	0.000	99.39
2	0.926	0.069	0.005	0.000	98.37	0.940	0.057	0.003	0.000	98.72	0.926	0.069	0.005	0.000	0.00	0.00	0.926	0.069	0.005	0.000	98.37	0.941	0.057	0.003	0.000	8.25	7.90	0.940	0.057	0.003	0.000	98.72
3	0.891	0.095	0.013	0.001	97.37	0.912	0.081	0.007	0.000	97.99	0.891	0.095	0.013	0.001	0.05	0.05	0.891	0.095	0.013	0.001	97.37	0.913	0.080	0.007	0.000	8.44	7.91	0.912	0.081	0.007	0.000	97.99
4	0.857	0.117	0.024	0.002	96.24	0.884	0.101	0.014	0.001	97.19	0.857	0.117	0.024	0.002	0.17	0.16	0.857	0.117	0.024	0.002	96.24	0.887	0.101	0.011	0.001	8.66	7.94	0.884	0.101	0.014	0.001	97.19
5	0.825	0.134	0.036	0.005	94.99	0.857	0.119	0.022	0.002	96.33	0.826	0.134	0.036	0.005	0.37	0.33	0.825	0.134	0.036	0.005	94.99	0.863	0.120	0.017	0.001	8.90	7.98	0.857	0.119	0.022	0.002	96.33
6	0.794	0.148	0.049	0.010	93.61	0.831	0.135	0.030	0.004	95.40	0.796	0.148	0.049	0.008	0.64	0.56	0.794	0.148	0.049	0.010	93.61	0.839	0.137	0.022	0.002	9.15	8.03	0.831	0.135	0.030	0.004	95.40
7	0.764	0.159	0.061	0.016	92.13	0.806	0.148	0.039	0.007	94.40	0.768	0.159	0.061	0.012	0.98	0.84	0.764	0.159	0.061	0.016	92.13	0.817	0.154	0.027	0.003	9.39	8.07	0.806	0.148	0.039	0.007	94.40
8	0.735	0.167	0.074	0.024	90.54	0.782	0.159	0.049	0.010	93.35	0.742	0.167	0.074	0.017	1.36	1.14	0.735	0.167	0.074	0.024	90.54	0.796	0.169	0.032	0.003	9.64	8.10	0.782	0.159	0.049	0.010	93.35
9	0.707	0.173	0.086	0.034	88.85	0.758	0.169	0.059	0.015	92.23	0.718	0.173	0.086	0.023	1.77	1.46	0.707	0.173	0.086	0.034	88.85	0.776	0.183	0.036	0.004	9.88	8.12	0.758	0.169	0.059	0.015	92.23
10	0.680	0.177	0.097	0.045	87.09	0.735	0.177	0.068	0.020	91.07	0.696	0.178	0.097	0.028	2.20	1.77	0.680	0.177	0.097	0.045	87.09	0.757	0.197	0.041	0.005	10.11	8.13	0.735	0.177	0.068	0.020	91.07
11	0.655	0.180	0.108	0.058	85.26	0.713	0.184	0.078	0.026	89.85	0.677	0.181	0.108	0.034	2.64	2.08	0.655	0.180	0.108	0.058	85.26	0.739	0.209	0.045	0.006	10.33	8.13	0.713	0.184	0.078	0.026	89.85
12	0.630	0.182	0.117	0.072	83.37	0.691	0.189	0.087	0.033	88.59	0.660	0.184	0.117	0.039	3.08	2.37	0.630	0.182	0.117	0.072	83.37	0.723	0.221	0.049	0.007	10.54	8.12	0.691	0.189	0.087	0.033	88.59
13	0.606	0.182	0.125	0.087	81.43	0.670	0.193	0.096	0.040	87.28	0.645	0.185	0.126	0.045	3.50	2.64	0.606	0.182	0.125	0.087	81.43	0.707	0.232	0.053	0.008	10.75	8.10	0.670	0.193	0.096	0.040	87.28
14	0.583	0.181	0.133	0.103	79.45	0.650	0.197	0.105	0.049	85.94	0.632	0.185	0.134	0.050	3.91	2.88	0.583	0.181	0.133	0.103	79.45	0.692	0.242	0.057	0.009	10.94	8.07	0.650	0.197	0.105	0.049	85.94
15	0.561	0.180	0.139	0.120	77.45	0.630	0.199	0.113	0.058	84.56	0.620	0.185	0.140	0.055	4.29	3.10	0.561	0.180	0.139	0.120	77.45	0.678	0.252	0.060	0.009	11.12	8.02	0.630	0.199	0.113	0.058	84.56
16	0.540	0.178	0.144	0.138	75.43	0.611	0.200	0.121	0.068	83.15	0.610	0.185	0.146	0.059	4.64	3.28	0.540	0.178	0.144	0.138	75.43	0.665	0.261	0.064	0.010	11.29	7.97	0.611	0.200	0.121	0.068	83.15
17	0.520	0.175	0.149	0.157	73.40	0.592	0.201	0.128	0.079	81.72	0.602	0.184	0.151	0.063	4.97	3.43	0.520	0.175	0.149	0.157	73.40	0.653	0.270	0.067	0.011	11.46	7.91	0.592	0.201	0.128	0.079	81.72
18	0.500	0.172	0.152	0.176	71.36	0.574	0.202	0.134	0.090	80.26	0.595	0.183	0.155	0.067	5.26	3.56	0.500	0.172	0.152	0.176	71.36	0.641	0.278	0.070	0.012	11.61	7.85	0.574	0.202	0.134	0.090	80.26
19	0.481	0.169	0.155	0.196	69.33	0.557	0.201	0.140	0.102	78.79	0.589	0.181	0.159	0.070	5.53	3.66	0.481	0.169	0.155	0.196	69.33	0.630	0.286	0.072	0.012	11.76	7.77	0.557	0.201	0.140	0.102	78.79
20	0.463	0.165	0.156	0.216	67.32	0.540	0.200	0.145	0.114	77.30	0.585	0.180	0.162	0.073	5.76	3.73	0.463	0.165	0.156	0.216	67.32	0.620	0.293	0.075	0.013	11.89	7.70	0.540	0.200	0.145	0.114	77.30

BRIDGE SUPERSTRUCTURE PROJECTIONS (20 OF 200 YEAR ANALYSIS)

Forecast condition and cost - Bridge superstructures

	Pure deterioration - no maint					Pure deterioration - routine maint					Worst-first scenario					($M)	Worst-first - typical bridge					Preservation scenario					($M)	Preservation - typical bridge				
Year	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health
0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.93	0.93	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	1.50	1.50	1.000	0.000	0.000	0.000	100.0
1	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	99.69	0.977	0.023	0.000	0.000	0.93	0.91	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	1.75	1.72	0.985	0.015	0.000	0.000	99.69
2	0.955	0.044	0.002	0.000	99.05	0.970	0.030	0.001	0.000	99.37	0.955	0.044	0.002	0.000	0.93	0.89	0.955	0.044	0.002	0.000	99.05	0.970	0.029	0.001	0.000	2.00	1.92	0.970	0.030	0.001	0.000	99.37
3	0.933	0.063	0.004	0.000	98.52	0.955	0.043	0.002	0.000	99.03	0.933	0.063	0.004	0.000	1.01	0.95	0.933	0.063	0.004	0.000	98.52	0.957	0.041	0.002	0.000	2.26	2.12	0.955	0.043	0.002	0.000	99.03
4	0.912	0.080	0.008	0.000	97.96	0.940	0.056	0.004	0.000	98.68	0.912	0.080	0.008	0.000	1.22	1.12	0.912	0.080	0.008	0.000	97.96	0.944	0.052	0.003	0.000	2.53	2.32	0.940	0.056	0.004	0.000	98.68
5	0.891	0.095	0.013	0.001	97.35	0.926	0.068	0.006	0.000	98.31	0.891	0.095	0.013	0.001	1.58	1.41	0.891	0.095	0.013	0.001	97.35	0.933	0.062	0.005	0.000	2.82	2.53	0.926	0.068	0.006	0.000	98.31
6	0.871	0.109	0.019	0.002	96.71	0.912	0.079	0.009	0.000	97.93	0.871	0.109	0.019	0.002	2.11	1.85	0.871	0.109	0.019	0.002	96.71	0.921	0.071	0.007	0.000	3.12	2.74	0.912	0.079	0.009	0.000	97.93
7	0.851	0.122	0.025	0.003	96.03	0.898	0.089	0.012	0.001	97.53	0.851	0.122	0.025	0.002	2.81	2.41	0.851	0.122	0.025	0.003	96.03	0.911	0.080	0.009	0.000	3.43	2.95	0.898	0.089	0.012	0.001	97.53
8	0.831	0.133	0.031	0.005	95.32	0.884	0.099	0.016	0.001	97.11	0.832	0.133	0.031	0.004	3.67	3.08	0.831	0.133	0.031	0.005	95.32	0.901	0.087	0.011	0.001	3.76	3.16	0.884	0.099	0.016	0.001	97.11
9	0.812	0.143	0.038	0.007	94.56	0.871	0.108	0.020	0.002	96.68	0.814	0.143	0.038	0.005	4.69	3.85	0.812	0.143	0.038	0.007	94.56	0.891	0.094	0.014	0.001	4.09	3.36	0.871	0.108	0.020	0.002	96.68
10	0.794	0.152	0.045	0.009	93.78	0.857	0.116	0.024	0.002	96.23	0.796	0.152	0.045	0.006	5.84	4.70	0.794	0.152	0.045	0.009	93.78	0.883	0.101	0.016	0.001	4.42	3.56	0.857	0.116	0.024	0.002	96.23
11	0.776	0.160	0.052	0.012	92.96	0.844	0.124	0.029	0.003	95.77	0.780	0.160	0.052	0.008	7.12	5.60	0.776	0.160	0.052	0.012	92.96	0.874	0.106	0.018	0.001	4.75	3.74	0.844	0.124	0.029	0.003	95.77
12	0.758	0.167	0.059	0.016	92.11	0.831	0.131	0.033	0.004	95.30	0.763	0.167	0.059	0.010	8.50	6.55	0.758	0.167	0.059	0.016	92.11	0.866	0.112	0.020	0.001	5.08	3.92	0.831	0.131	0.033	0.004	95.30
13	0.741	0.173	0.067	0.020	91.23	0.819	0.138	0.038	0.005	94.81	0.748	0.173	0.067	0.012	9.96	7.51	0.741	0.173	0.067	0.020	91.23	0.859	0.117	0.022	0.002	5.41	4.08	0.819	0.138	0.038	0.005	94.81
14	0.724	0.178	0.074	0.024	90.32	0.806	0.144	0.043	0.007	94.31	0.733	0.179	0.074	0.014	11.49	8.47	0.724	0.178	0.074	0.024	90.32	0.852	0.122	0.024	0.002	5.73	4.23	0.806	0.144	0.043	0.007	94.31
15	0.707	0.183	0.081	0.029	89.39	0.794	0.150	0.048	0.008	93.79	0.720	0.184	0.081	0.016	13.07	9.43	0.707	0.183	0.081	0.029	89.39	0.845	0.126	0.027	0.002	6.05	4.36	0.794	0.150	0.048	0.008	93.79
16	0.691	0.187	0.088	0.035	88.42	0.782	0.156	0.053	0.010	93.26	0.706	0.188	0.088	0.018	14.68	10.37	0.691	0.187	0.088	0.035	88.42	0.839	0.130	0.028	0.002	6.35	4.48	0.782	0.156	0.053	0.010	93.26
17	0.675	0.190	0.094	0.040	87.44	0.770	0.161	0.058	0.012	92.72	0.694	0.191	0.094	0.020	16.32	11.27	0.675	0.190	0.094	0.040	87.44	0.833	0.134	0.030	0.003	6.65	4.59	0.770	0.161	0.058	0.012	92.72
18	0.660	0.193	0.101	0.047	86.43	0.758	0.165	0.064	0.013	92.17	0.682	0.194	0.101	0.022	17.95	12.14	0.660	0.193	0.101	0.047	86.43	0.827	0.138	0.032	0.003	6.93	4.68	0.758	0.165	0.064	0.013	92.17
19	0.645	0.195	0.107	0.054	85.41	0.746	0.169	0.069	0.016	91.61	0.671	0.197	0.107	0.025	19.59	12.95	0.645	0.195	0.107	0.054	85.41	0.822	0.141	0.034	0.003	7.20	4.76	0.746	0.169	0.069	0.016	91.61
20	0.630	0.197	0.113	0.061	84.37	0.735	0.173	0.074	0.018	91.03	0.661	0.199	0.113	0.027	21.20	13.72	0.630	0.197	0.113	0.061	84.37	0.817	0.144	0.036	0.003	7.47	4.83	0.735	0.173	0.074	0.018	91.03

BRIDGE SUBSTRUCTURE PROJECTIONS (20 OF 200 YEAR ANALYSIS)

Forecast condition and cost - Bridge substructures

	Pure deterioration - no maint					Pure deterioration - routine maint					Worst-first scenario					($M)	Worst-first - typical bridge					Preservation scenario					($M)	Preservation - typical bridge				
Year	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health	Good	Satis	Fair	Poor	Cost	PV$	Good	Satis	Fair	Poor	Health
0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.00	0.00	1.000	0.000	0.000	0.000	100.0	1.000	0.000	0.000	0.000	0.00	0.00	1.000	0.000	0.000	0.000	100.0
1	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	99.69	0.977	0.023	0.000	0.000	0.00	0.00	0.977	0.023	0.000	0.000	99.54	0.985	0.015	0.000	0.000	0.00	0.00	0.985	0.015	0.000	0.000	99.69
2	0.955	0.044	0.002	0.000	99.05	0.970	0.030	0.001	0.000	99.37	0.955	0.044	0.002	0.000	0.00	0.00	0.955	0.044	0.002	0.000	99.05	0.970	0.030	0.001	0.000	0.01	0.01	0.970	0.030	0.001	0.000	99.37
3	0.933	0.063	0.004	0.000	98.52	0.955	0.043	0.002	0.000	99.03	0.933	0.063	0.004	0.000	0.00	0.00	0.933	0.063	0.004	0.000	98.52	0.955	0.043	0.002	0.000	0.03	0.03	0.955	0.043	0.002	0.000	99.03
4	0.912	0.080	0.008	0.000	97.96	0.940	0.056	0.004	0.000	98.68	0.912	0.080	0.008	0.000	0.00	0.00	0.912	0.080	0.008	0.000	97.96	0.940	0.056	0.004	0.000	0.05	0.04	0.940	0.056	0.004	0.000	98.68
5	0.891	0.095	0.013	0.001	97.35	0.926	0.068	0.006	0.000	98.31	0.891	0.095	0.013	0.001	0.00	0.00	0.891	0.095	0.013	0.001	97.35	0.926	0.068	0.006	0.000	0.07	0.07	0.926	0.068	0.006	0.000	98.31
6	0.871	0.109	0.019	0.002	96.71	0.912	0.079	0.009	0.000	97.93	0.871	0.109	0.019	0.002	0.00	0.00	0.871	0.109	0.019	0.002	96.71	0.912	0.079	0.008	0.000	0.10	0.09	0.912	0.079	0.009	0.000	97.93
7	0.851	0.122	0.025	0.003	96.03	0.898	0.089	0.012	0.001	97.53	0.851	0.122	0.025	0.002	0.00	0.00	0.851	0.122	0.025	0.003	96.03	0.898	0.090	0.011	0.000	0.14	0.12	0.898	0.089	0.012	0.001	97.53
8	0.831	0.133	0.031	0.005	95.32	0.884	0.099	0.016	0.001	97.11	0.832	0.133	0.031	0.004	0.00	0.00	0.831	0.133	0.031	0.005	95.32	0.885	0.100	0.014	0.001	0.17	0.15	0.884	0.099	0.016	0.001	97.11
9	0.812	0.143	0.038	0.007	94.56	0.871	0.108	0.020	0.002	96.68	0.814	0.143	0.038	0.005	0.00	0.00	0.812	0.143	0.038	0.007	94.56	0.871	0.110	0.018	0.001	0.21	0.17	0.871	0.108	0.020	0.002	96.68
10	0.794	0.152	0.045	0.009	93.78	0.857	0.116	0.024	0.002	96.23	0.796	0.152	0.045	0.006	0.00	0.00	0.794	0.152	0.045	0.009	93.78	0.858	0.119	0.021	0.001	0.25	0.20	0.857	0.116	0.024	0.002	96.23
11	0.776	0.160	0.052	0.012	92.96	0.844	0.124	0.029	0.003	95.77	0.780	0.160	0.052	0.008	0.01	0.00	0.776	0.160	0.052	0.012	92.96	0.846	0.128	0.025	0.002	0.29	0.23	0.844	0.124	0.029	0.003	95.77
12	0.758	0.167	0.059	0.016	92.11	0.831	0.131	0.033	0.004	95.30	0.763	0.167	0.059	0.010	0.01	0.01	0.758	0.167	0.059	0.016	92.11	0.833	0.136	0.028	0.002	0.34	0.26	0.831	0.131	0.033	0.004	95.30
13	0.741	0.173	0.067	0.020	91.23	0.819	0.138	0.038	0.005	94.81	0.748	0.173	0.067	0.012	0.01	0.01	0.741	0.173	0.067	0.020	91.23	0.821	0.145	0.032	0.002	0.38	0.29	0.819	0.138	0.038	0.005	94.81
14	0.724	0.178	0.074	0.024	90.32	0.806	0.144	0.043	0.007	94.31	0.733	0.179	0.074	0.014	0.01	0.01	0.724	0.178	0.074	0.024	90.32	0.809	0.152	0.036	0.003	0.43	0.31	0.806	0.144	0.043	0.007	94.31
15	0.707	0.183	0.081	0.029	89.39	0.794	0.150	0.048	0.008	93.79	0.720	0.184	0.081	0.016	0.01	0.01	0.707	0.183	0.081	0.029	89.39	0.797	0.160	0.040	0.003	0.47	0.34	0.794	0.150	0.048	0.008	93.79
16	0.691	0.187	0.088	0.035	88.42	0.782	0.156	0.053	0.010	93.26	0.706	0.188	0.088	0.018	0.01	0.01	0.691	0.187	0.088	0.035	88.42	0.786	0.167	0.044	0.003	0.52	0.37	0.782	0.156	0.053	0.010	93.26
17	0.675	0.190	0.094	0.040	87.44	0.770	0.161	0.058	0.012	92.72	0.694	0.191	0.094	0.020	0.01	0.01	0.675	0.190	0.094	0.040	87.44	0.775	0.174	0.048	0.004	0.56	0.39	0.770	0.161	0.058	0.012	92.72
18	0.660	0.193	0.101	0.047	86.43	0.758	0.165	0.064	0.013	92.17	0.682	0.194	0.101	0.022	0.02	0.01	0.660	0.193	0.101	0.047	86.43	0.764	0.180	0.052	0.004	0.61	0.41	0.758	0.165	0.064	0.013	92.17
19	0.645	0.195	0.107	0.054	85.41	0.746	0.169	0.069	0.016	91.61	0.671	0.197	0.107	0.025	0.02	0.01	0.645	0.195	0.107	0.054	85.41	0.753	0.186	0.055	0.005	0.66	0.43	0.746	0.169	0.069	0.016	91.61
20	0.630	0.197	0.113	0.061	84.37	0.735	0.173	0.074	0.018	91.03	0.661	0.199	0.113	0.027	0.02	0.01	0.630	0.197	0.113	0.061	84.37	0.743	0.193	0.059	0.005	0.70	0.45	0.735	0.173	0.074	0.018	91.03

Bridge Decks		
	Typical	Worst First
Undiscounted Sum	4,307,399	9,890,119
Net Present Value (NPV)	801,887	1,803,674
Equivalent Uniform Annual Cost (EUAC)	17,872	40,198
% of initial cost	159%	365%
Bridge Superstructures		
	Typical	Worst First
Undiscounted Sum	1,599,110	6,088,156
Net Present Value (NPV)	277,749	962,546
Equivalent Uniform Annual Cost (EUAC)	6,190	21,452
% of initial cost	59%	225%
Bridge Substructures		
	Typical	Worst First
Undiscounted Sum	2,555,022	6,103,786
Net Present Value (NPV)	347,826	964,992
Equivalent Uniform Annual Cost (EUAC)	7,752	21,507
% of initial cost	94%	225%

Note: All costs in $/bridge
Initial costs not included in analysis

Chapter 7

PERFORMANCE GAPS: SUPPLEMENTAL INFORMATION

PERFORMANCE GAPS: SUPPLEMENTAL INFORMATION

Overview

Chapter 3 of the TAMP describes MnDOT's business practices, performance measures, and targets used to monitor and report asset conditions, as well as the new target terminology used in the TAMP. Figure 3-1 summarizes these new key terms associated with targets, which now override the language used to describe performance outcomes in MnSHIP. Moving forward, MnDOT will use the term "target" to denote desired outcomes. The term "plan outcome" will be used to identify outcomes to which MnDOT is managing, while the term "expected outcome" will be used to demonstrate the results of predictive modeling performed using various analytical tools.

Note:

Chapter 7 of the TAMP contains all the necessary information pertaining to current and targeted performance levels. Hence, no additional information is provided in this chapter of the Technical Guide.

Chapter 8

FINANCIAL PLAN AND INVESTMENT STRATEGIES: SUPPLEMENTAL INFORMATION

FINANCIAL PLAN AND INVESTMENT STRATEGIES: SUPPLEMENTAL INFORMATION

Overview

This chapter provides a description of the asset management investment strategies developed and how they were incorporated into the TAMP. While specific strategies were laid out for investments in pavement and bridge assets in the Minnesota State Highway Investment Plan (MnSHIP), the investment strategy for other ”Roadside Infrastructure” assets (including, but not limited to, highway culverts, deep stormwater tunnels, overhead sign structures and high-mast light tower structures) was generic and focused primarily on maintaining operable conditions at expected funding levels. MnSHIP does not explicitly break out the asset types within the Roadside Infrastructure investment category. Therefore, as a part of the TAMP development process, investment strategies for highway culverts, deep stormwater tunnels, overhead sign structures and high-mast light tower structures were examined more closely and tools were developed to estimate the level of investment needed to maintain these assets over the 10-year period covered in the TAMP.

Process

This chapter includes brief descriptions of the investment strategies developed in MnSHIP and the Highway Systems Operations Plan (HSOP) and how they were incorporated into the TAMP. This is followed by a discussion on the process for developing investment strategies for highway culverts, overhead sign structures, and high-mast light tower structures. Finally, a summary is provided regarding the envisioned process changes for how future TAMPs will inform MnSHIP.

INVESTMENT STRATEGIES

As discussed in Chapter 2 of the TAMP, tradeoffs between investment levels, performance levels, and risks were evaluated as a part of the MnSHIP development process to understand and demonstrate the impact of a holistic investment decision methodology. Three approaches were considered during the MnSHIP scenario planning process:

- **Approach A**: Focus on maintaining existing infrastructure on the entire system, leaving little-to-no ability to invest in local priorities and mobility.
- **Approach B (Adopted)**: Maintain an approach similar to MnDOT’s current priorities – emphasizing pavements, bridges, and safety – with some improvements in local priorities and mobility.
- **Approach C**: Greater emphasis on mobility for all modes and addressing local concerns at priority locations, which will result in significant declines in infrastructure condition on most state highways.

Considering two primary risks – (a) failure to implement federal policy set in MAP-21 and (b) failure to preserve the state’s bond rating by falling below the thresholds set in Government Accounting Standards Board Statement 34 (GASB 34) – the investment strategy adopted for the first 10 years focused on maintaining a diverse mix of improvements to reduce overall life-cycle costs, as well as enhancing mobility and MnDOT’s ability to respond to evolving needs. The asset management investment strategy laid out in MnSHIP is summarized in Figure 8-1.

Figure 8-1: MnSHIP Investment Strategies

INVESTMENT CATEGORY		10-YEAR STRATEGY
Asset Management	**Pavements**	• Maintain conditions on NHS pavements. • Allow non-NHS pavements to deteriorate to a slightly lower condition, while maintaining safe conditions for the traveling public. • Use low-cost maintenance and preservation strategies. • Use performance-based design to select projects that address pavement and safety needs. • Alternate bidding and contracting mechanisms to determine the most cost-effective solutions. • Research/evaluate innovative materials and construction techniques.
	Bridges	• Maintain condition of NHS bridges. • Allow non-NHS bridges to deteriorate to a slightly lower condition, while keeping them safe and operable to the traveling public. • Invest in state highway bridges at optimum points in their life- cycles to ensure safety and structural health. • Conduct bridge inspections to ensure timely application of maintenance and capital improvements. • Apply appropriate measures to ensure bridges achieve or exceed their intended service lives.
	Roadside Infrastructure	• Maintain culverts, signals, sign structures, sign panels, lighting structures, rest areas, barriers, and retaining walls in safe operable conditions with the understanding that their general conditions are expected to deteriorate with current expected funding levels.

In addition to the capital investment strategies outlined in MnSHIP, HSOP provides a framework for managing key operations and maintenance activities throughout Minnesota and complements other strategic planning efforts, such as MnDOT's District Highway Investment Plans, which focus on capital infrastructure needs. Specific maintenance/operations strategies to address a host of critical issues faced by MnDOT – ranging from aging infrastructure to increased responsibilities (as a result of state and federal mandates) to declining staff levels – are discussed in detail in HSOP (and summarized in Chapter 2 of the TAMP).

The strategies laid out in MnSHIP and HSOP are carried forward in MnDOT's TAMP. Moving forward, future TAMPs are expected to inform MnSHIP updates and streamline the investment planning process (discussed later).

ASSET INVESTMENT STRATEGIES PRESENTED IN THE TAMP

The specific investment strategies adopted for the asset categories discussed in the TAMP are summarized below.

PAVEMENTS

After performance targets were established for pavements (see Chapter 3 of the TAMP), investment levels and strategies to achieve those targets were developed using MnDOT's Highway Pavement Management Application (HPMA) by modeling performance-constrained scenarios. Because this effort was already completed as a part of the MnSHIP process, the results were carried forward and adopted in the TAMP.

BRIDGES

After performance targets were established for bridges (see Chapter 3 of the TAMP), investment levels and strategies to achieve those targets were developed using MnDOT's Pontis bridge management system, for bridge inventory and condition data, and MnDOT's Bridge Replacement and

Improvement Management System (BRIM), for prioritizing projects and developing network-level cost estimates. This effort, too, was already completed as a part of the MnSHIP process, and these results were also carried forward and adopted in the TAMP.

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS (HYDRAULIC INFRASTRUCTURE)

As discussed in the TAMP, MnSHIP does not explicitly break out the asset categories within the Roadside Infrastructure investment category, but highway culverts and deep stormwater tunnel needs are provided for in the investment plan. Costs specific to culvert and stormwater tunnel needs were obtained from the MnSHIP investment planning team for reporting in the TAMP.

MnDOT recognizes that fixing hydraulic assets in Very Poor condition (HydInfra Condition Level 4) is more expensive than repairing them before they have reached this condition; cheaper treatments are not feasible when assets deteriorate to a Very Poor condition. Therefore, and due to the high cost and risk of catastrophic failure associated with these assets, MnDOT has adopted a preventive maintenance strategy of applying treatments to culverts and tunnels before they reach a condition of Very Poor.

A spreadsheet-based repair projection model was developed by MnDOT to estimate the repair needs for highway culverts over the 10-year TAMP planning horizon. The projections make some general assumptions:

- Culverts degrading to a Very Poor condition were previously one level better (HydInfra Condition Level 3: Poor) and any fixes applied to culverts in Very Poor and Poor conditions restore the conditions to an Excellent (HydInfra Condition Level 1) or a Fair (HydInfra Condition Level 2) level.
- No new culverts are built over the next 10 years and none of the existing culverts are taken out of service.
- The oldest pipes are fixed first.

Using the assumptions listed above and adopting a simple deterioration model, it was estimated that approximately 600 culverts in Very Poor condition would need to be repaired each year over the next 10 years to achieve the recommended performance targets.

OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES (OTHER TRAFFIC STRUCTURES)

The investment strategy for overhead sign structures and high-mast light tower structures was developed using an approach that considers the fraction of structures in various condition levels and makes a balanced investment according to expert input from the Other Traffic Structures Work Group.

Investment needs for these assets are based on inspection costs (which account for the bulk of the need) and assumptions about treatment needs over the next 10 years (based on discussions with the Work Group). A spreadsheet tool was developed to assist with determination of the investment needs.

INVESTMENT PLANNING WORKSHOPS

Two formal workshops were held to discuss the recommendations for investment strategies to be adopted as part of the TAMP:

- **Investment Planning Workshop #1 (November 2013)**: Preliminary recommendations for the investment strategies and performance targets were discussed during this workshop. Targets for pavements and bridges were tweaked based on discussions held during this meeting. The group (TAMP Steering Committee plus representatives from MnDOT's senior leadership) also recognized that targets for highway culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures were largely based on expert opinion for this first TAMP, but that future TAMPs will work toward developing objective and outcome-based targets.
- **Investment Planning Workshop #2 (January 2013)**: This workshop focused on finalizing the investment levels and performance targets that were incorporated into the TAMP.

FUTURE PROCESS CHANGES

Because much of the investment planning process was already completed as a part of the MnSHIP process, the efforts were not duplicated for the TAMP. The results were validated, refined, and incorporated into the TAMP after approval by the Steering Committee. In order to establish a more streamlined process moving forward, the investment planning process will be conducted as a part of future TAMPs and the outcomes will serve as the basis for MnSHIP updates (for assets covered in the TAMP).

MnDOT is also in the process of implementing management systems for asset categories beyond pavements and bridges. These systems, collectively referred to as Transportation Asset Management Systems (TAMS), will allow MnDOT to better manage roadside infrastructure through an objective, data-driven approach, which will also improve the development of investment strategies and targets. The first TAMS implementation will focus on traffic signals and lighting.

Supporting Data and Documentation

As discussed earlier, spreadsheet tools were developed to estimate the level of investment required for hydraulic infrastructure and other traffic structures over the 10-year planning horizon covered in the TAMP. Examples of these tools are included as attachments at the end of the chapter.

Highway Culvert Target Methodology

Pipes quantity per condition category with NO FIXING

	year 0	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
condition 1,2	39810	39260	38710	38160	37610	37060	36510	35960	35410	34860	34310
condition 3	4739	4859	4979	5099	5219	5339	5459	5579	5699	5819	5939
condition 4	2844	3274	3704	4134	4564	4994	5424	5854	6284	6714	7144
										Total:	47393

FIXES NEEDED OVER 10 YEARS

condition 3 repairs for 10 years	2148
condition 3 repairs /year needed	215
condition 4 repairs for 10 years	5722
number of condition 4 repair /year needed	572
TOTAL FIXES PER YEAR	787

Prevision to reach 10-year targets/Amount of pipes required in each condition category

	year 0	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10	TARGET
condition 1,2	39810	40047	40284	40521	40758	40995	41232	41469	41706	41943	42180	42180
condition 3	4739	4645	4550	4455	4360	4265	4171	4076	3981	3886	3791	3791
condition 4	2844	2701	2559	2417	2275	2133	1991	1848	1706	1564	1422	1422
											Total:	47393

CURRENT CONDITIONS

	2012
% Condition 4	0.06
% Condition 3	0.1
% Condition 1,2	0.84
Total culverts	47393
Amount of pipes becoming condition 4/year	430
Amount of pipes becoming condition 3/year	550

	Percent
2022 target for condition 4	0.03
2022 target for condition 3	0.08
fixing capability /yr	430

Assumptions used for the previsions:

1 - We assume that the pipes degrading to condition 4 were previously condition 3 pipes. Similarly, pipes degrading to condition 3 were previously in condition 2.

2 - The prevision assumes that no extra pipes will be built and that no pipes will be taken away. We use a total of 47,393 pipes over the ten years.

3 - a fixed pipe returns to a condition 1 or 2 pipe.

Highway Culvert Repair Projection Model

CONDITION 4 CULVERTS

AGE

YEARS	?	1	2	3	4	5	6	7	8	9	10	count
0	2843											
1	2271	430										
2	1699	430	430	0	0	0	0	0	0	0	0	
3	1127	430	430	430	0	0	0	0	0	0	0	
4	555	430	430	430	430	0	0	0	0	0	0	
5	0	430	430	430	430	413	0	0	0	0	0	17
6	0	430	430	430	430	271	0	0	0	0	0	159
7	0	430	430	430	430	129	0	0	0	0	0	301
8	0	430	430	430	417	0	0	0	0	0	0	443
9	0	430	430	430	275	0	0	0	0	0	0	155
10	0	430	430	430	133	0	0	0	0	0	0	297

Number of Condition 4 repair/year 572

Fix existing condition 4		5
Fix New condition 4		
Added	year 1	6
	year 2	6
	year 3	6
	year 4	5
	year 5	5
	year 6	5
	year 7	5
	year 8	?
	year 9	?
	year 10	?

ASSUMPTIONS

1 - The oldest pipes are always fixed first

2 - 572 pipes are repaired each year

Summary of Current Overhead Sign Structure Condition

Overall Condition Rating	Description	SRF - Number of structures per rating	Structures that have Maintenance work done and/or planned construction work will move from 2,3,4,5 to 6	**7-2-13** Structures per condition rating	% of total		New Totals	New Percentages
2	Critical	143	**26**	117	6%		42	1.78%
3	Serious	257	**53**	204	11%		147	6.22%
4	Poor	423	**81**	342	18%		137	5.80%
5	Fair	357	**70**	287	15%		376	15.91%
6	Satisfactory	200	*49*	**430**	23%		1595	67.50%
7	Good	32	2	32	2%		60	2.54%
8	Very Good	3	0	3	0%		6	0.25%
			281	1415			2363	100.00%

230 moved to 6

CO Active Structures	1857
Retired per Metro	4
Not inspected	**438**
Condition Total	1415

Modified percentages after structures statewide have been included. All remaining 510 structures are reported to be in 100% good condition.

Poor	36%	62% (414) of these have loose anchorages/nuts
Fair	15%	
Good	25%	

For structures not inspected, the most reasonable assumption would be to go with the Good/Fair/Poor distribution observed for the structures inspected. This can be revised in the Asset Register

Based on inspected structures:

Poor	249	17.6%	77		326	13.8%
Fair	287	20.3%	89		376	15.9%
Good	879	62.1%	272	510	1661	70.3%
Totals	**1415**		**438**		2363	

Summary of Overhead Sign Structures Investment History

Metro	328
Total No.	475
Others	147

Total Statewide Figures (Based on Extrapolation of Metro Numbers Statewide)

Inspection Cycle	Year	No. of Structures Inspected	No of Structures Requiring: No Maintenance	Routine Maintenance	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation	Replacement
1	2012	149	120	22	NA	7	0	0
2	2011	301	203	59	NA	39	0	0
3	2010	49	26	19	NA	4	0	0
4	2009	310	256	54	NA	0	0	0
5	2007	55	30	25	NA	0	0	0
6	2005	142	101	12	NA	0	0	0
7	2003	155	155	0	NA	0	0	0
8	2001	181	181	0	NA	0	0	0
Avg. /yr		168		18.8%		17		
Std. Dev.		97						
Average + SD		265						

Only Metro

Inspection Cycle	Year	No. of Structures Inspected	No of Structures Requiring: No Maintenance	Routine Maintenance	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation	Replacement
1	2012	103	83	15	NA	5	0	0
2	2011	208	140	41	NA	27	0	0
3	2010	34	18	13	NA	3	0	0
4	2009	214	177	37	NA	0	0	0
5	2007	38	21	17	NA	0	0	0
6	2005	98	70	8	NA	0	0	0
7	2003	107	107	0	NA	0	0	0
8	2001	125	125	0	NA	0	0	0
Avg. /yr		116		18.8%		12		
Std. Dev.		67						
Average + SD		183						

Other Structures Statewide (Extrapolated from Metro numbers)

Inspection Cycle	Year	No. of Structures Inspected	No of Structures Requiring: No Maintenance	Routine Maintenance	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation	Replacement
1	2012	46	37	7	NA	2	0	0
2	2011	93	63	18	NA	12	0	0
3	2010	15	8	6	NA	1	0	0
4	2009	96	79	17	NA	0	0	0
5	2007	17	9	8	NA	0	0	0
6	2005	44	31	4	NA	0	0	0
7	2003	48	48	0	NA	0	0	0
8	2001	56	56	0	NA	0	0	0
Avg. /yr		52		18.8%		5		
Std. Dev.		30						
Average + SD		82						

Approach 1:

Assumptions:

1. 183 Structures are inspected each year from 2014 - 2023 (10 year period), which gives a total of 1830 inspections.
2. Average inspection cost of $1000/structure.
3. Average Routine maintenance cost of $500/structure, 18.8% of structures inspected receive routine maintenance per year.
4. Average replacement cost of $40,000/structure, assuming 1 structure replaced per year over next 10 years.
5. Minor rehabilitation cost assumed to be $2000 per structure (value not provided by work group), 12 strucures assumed to receive minor rehab per year.

Total Inspections 10-yr inspections	2650

		10-Yr Number	10-Yr Cost
Inspection Cost (per structure)	$1,000	2650	$2,650,006
Routine Maintenance Cost (per structure)	$500	499	$249,749
Minor Rehabilitation Cost (per structure)	$2,000	169	$337,907
Replacement Cost (per strucutre)	$40,000	10	$400,000
		Total	**$3,637,662**

Approach 2:

Assumptions:

1. Using a 5-year inspection cycle, assumed that 95 structures are inspected each each on an average.
2. Average inspection cost of $1000/structure.
3. Average Routine maintenance cost of $500/structure, 18.8% of structures inspected receive routine maintenance per year.
4. Average replacement cost of $40,000/structure, assuming 1 structure replaced per year over next 10 years.
5. Minor rehabilitation cost assumed to be $2000 per structure (value not provided by work group), 12 strucures assumed to receive minor rehab per year.

Total Inspections 10-yr inspections	950

		10-Yr Number	10-Yr Cost
Inspection Cost (per structure)	$1,000	950	$950,000
Routine Maintenance Cost (per structure)	$500	179	$89,532
Minor Rehabilitation Cost (per structure)	$2,000	169	$337,907
Replacement Cost (per strucutre)	$40,000	10	$400,000
		Total	**$1,777,439**

Summary of Overhead Sign Structures Investments Needed to Achieve 10-year Targets

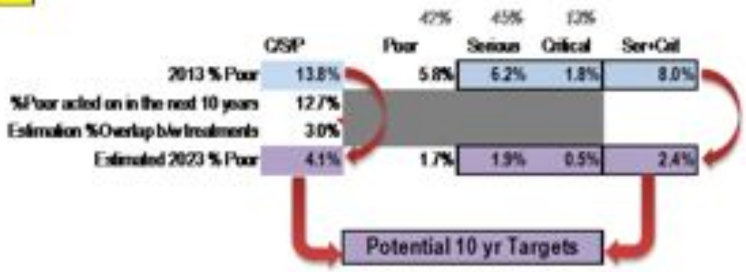
Inventory			Inspections			Tighten Nuts			Remove Grout			Regrade footing, Replace weld...			Replace foundation...			Replace Structure			10-Yr Investment
Condition	Total	Percent	No. of Cycles	Number	Cost	Fraction	Number	Cost	Fraction	Number	Cost	Fraction	Number	Cost	Fraction	Number	Cost	Fraction	Number	Cost	
Good	1661	70%	2	2335	$2,682,654	0%	0	$0	0%	0	$0	0%	0	$0	0%	0	$0	0%	0	$0	$2,682,654
Fair	376	16%	2	120	$606,979	0%	0	$0	0%	0	$0	0%	0	$0	0%	0	$0	0%	0	$0	$606,979
Poor	326	14%	2	90	$526,612	40%	111	$55,433	15%	42	$41,575	10%	28	$83,149	17%	47	$1,177,948	10%	28	$2,355,896	$4,240,613
Total	2363	100%			$3,816,245			$55,433			$41,575			$83,149			$1,177,948			$2,355,896	$7,530,246

	Inspections	Tighten Nuts	Remove Grout	Regrade footing, Replace weld...	Replace foundation...	Replace Structure
Avg. Unit Costs/structure	$950	$500	$1,000	$3,000	$25,000	$85,000
Inspection %	85%	85%	85%	85%	85%	85%

User input

Computation

Output



Chapter 9

IMPLEMENTATION AND FUTURE DEVELOPMENTS: SUPPLEMENTAL INFORMATION

IMPLEMENTATION AND FUTURE DEVELOPMENTS: SUPPLEMENTAL INFORMATION

Overview

This chapter describes a process to help MnDOT decide which assets to consider adding when it develops future TAMPs. A few asset management tools and techniques that MnDOT could potentially implement in the future are also discussed.

Process

This section describes a generic process that MnDOT can use to help identify future enhancements to the TAMP. For instance, it includes a process for identifying assets that can be added to future versions of the TAMP. It also includes information on the gap analysis technique used for evaluating current and desired practices and for identifying priorities for actions needed to achieve agency goals. Other performance metrics are also included that can be used to track the financial sustainability of MnDOT's investments.

INCORPORATING OTHER ASSETS IN THE TAMP

Figure 9-1 depicts a process for evaluating the availability and maturity of data for a given asset category, to determine whether it can or needs to be included in the TAMP.

Figure 9-1: Process Used to Collect and Summarize Asset Data

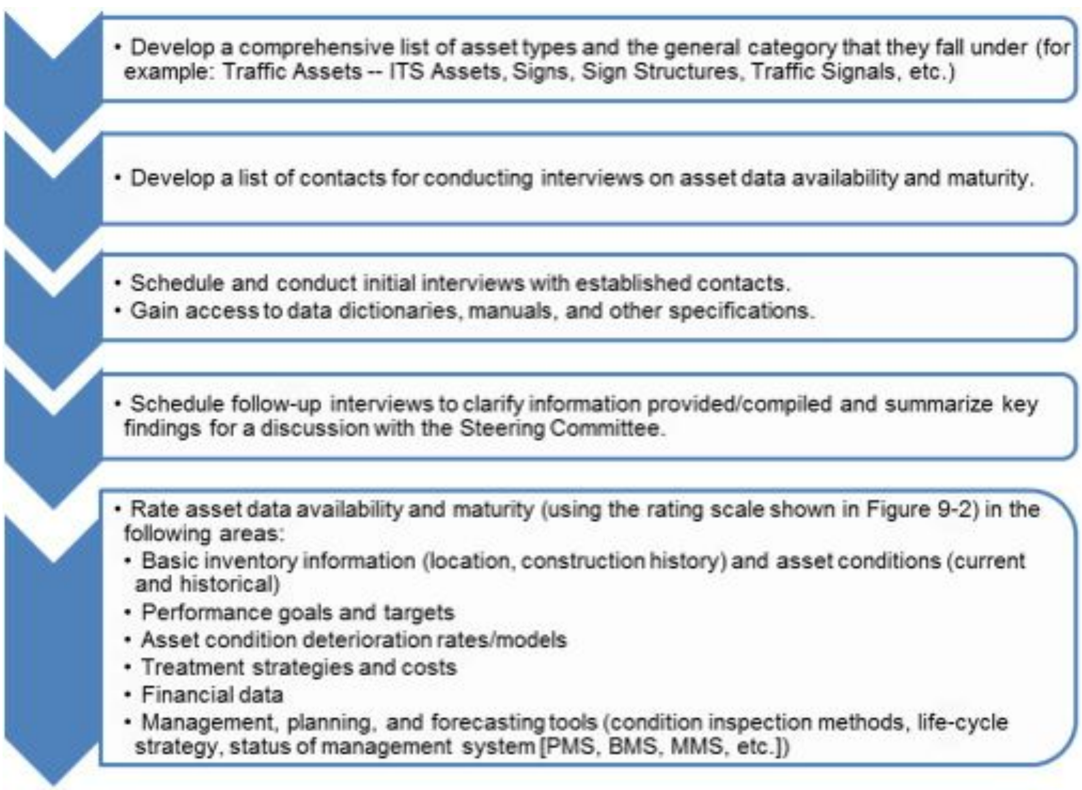


Figure 9-2: Rating Scale for Data Availability and Maturity Assessment

RATING	DESCRIPTION
1	Readily available with minimum manipulation, well-established process, data verified and high-confidence in system
2	Intermediate availability, requires moderate level of manipulation to convert data to a usable format, efforts to improve systems in place
3	Difficult to use data in current format/significant manipulations required, no management system but data tracked through spreadsheets, somewhat documented system
4	Information not readily available/very little data available, no management system in place, complete lack or very little documentation on process
5	Not available/unable to assess, No management system in place

After the data availability and maturity assessments are made, the results should be organized into a matrix (similar to the one shown in Figure 9-3) for comparing the asset categories evaluated.

Figure 9-3: Sample Data Availability and Maturity Level Assessment Summary

ASSET	RATING FOR:					
	BASIC INVENTORY AND CONDITIONS	PERFORMANCE GOALS AND, TARGETS	TREATMENT STRATEGIES AND COSTS	DETERIORATION RATES	FINANCIAL DATA	MANAGEMENT PLANNING, AND FORECASTING
Pavements	1	1	2	2	2	2
Bridges	1	3	3	5	2	4
ITS Assets	2	4	3	5	2	4
Slopes	2	3	3	5	5	5
Guard Rails, Barriers, Impact Attenuators	3	5	3	5	5	4

It should be noted that data availability and maturity cannot be the only driving factors for determination of the final list of assets that will be included in the TAMP; other factors to consider include:

- Level of investment in the assets, including either financial investments or personnel time
- Contribution to the agency's risk levels
- Reporting requirements, legislation, or mandates (e.g. MAP-21 requirements, EPA, GASB, and MnDOT internal requirements)
- Departmental strategic priorities
- Historical practices
- The need to balance transportation partner needs and requests

The final decision regarding the assets to be included should be conducted through a workshop facilitated by the Asset Management Steering Committee and involving members of the asset Work Groups and other MnDOT stakeholders.

GAP ANALYSIS

A gap analysis is a technique that provides an objective and structured process for evaluating current and desired practices and identifying priority actions needed to achieve agency goals. A gap analysis process typically includes a scoring system that allows an agency to rate a specific set of criteria (developed for a specific topic) in order to determine the maturity level for each component included in the assessment.

A recent National Cooperative Highway Research Program project (NCHRP 08-90) resulted in the development of an updated gap analysis spreadsheet tool for asset management. The tool considers MAP-21 requirements and will help state transportation departments identify actions to include in their asset management improvement plans. The gap analysis tool (a) enables an objective assessment of agency practices; (b) introduces a framework for assessing gaps in legislated requirements or core capabilities; (c) provides a tool to facilitate data analysis; and (d) simplifies the analysis and reporting of this information.

The final products from this study are expected to be available in the fall of 2014 through NCHRP[1]. Transportation agencies could potentially use the tool to identify, evaluate, and prioritize areas for improvement through a more structured and streamlined approach.

OTHER PERFORMANCE METRICS

A study published by the FHWA[2] examines a host of proposed performance measures that are centered on an *Asset Sustainability Index* (ASI). The report defines ASI as *a composite metric computed by dividing the amount budgeted on infrastructure maintenance and preservation[3] over time by the amount needed to achieve a specific infrastructure target*. Mathematically, it is:

$$ASI = \frac{Amount\ Budgeted}{Amount\ Needed}$$

An ASI value of 1.0 is considered an ideal scenario when all the needs are accounted for. The ASI can be used in time-series plots to analyze long-term trends, and can also be used as a combined metric to include all the assets being managed by an agency. Or, it can focus on a specific asset category or activity (e.g. pavements, bridges, maintenance) to develop a sustainability ratio metric specific to that asset/activity.

Although the ASI is a relatively simple concept, time-series ASI data can be a very informative metric for long-term (and short-term) planning purposes. An example of how Asset Sustainability Indices can be used to visualize program needs is shown in Figure 9-4.

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[1] NCHRP (2014). Transportation Asset Management Gap Analysis Tool (Web Link)
[2] FHWA (2012). Asset Sustainability Index: A Proposed Measure for Long-Term Performance (Web Link)
[3] The terms "maintenance" and "preservation" are generically used to include routine, reactive, preventive, rehabilitative, and even replacement activities that contribute to the achievement of an infrastructure condition target.

Figure 9-4: Illustration of Asset Sustainability Indices (Output)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Pavements	0.83	0.82	0.81	0.81	0.80	0.79	0.78	0.77	0.77	0.76
Major Routes	0.80	0.79	0.78	0.78	0.77	0.76	0.75	0.75	0.74	0.73
Arterials	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Collectors	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Pavement Rehabilitation/Replacement	0.40	0.40	0.39	0.39	0.38	0.38	0.38	0.37	0.37	0.37
Pavement Preventive Mainenance	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Bridges	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82
Preventive Maintenance/Preservation	0.90	0.89	0.88	0.87	0.86	0.86	0.85	0.84	0.83	0.82
Sub and Superstructures	0.87	0.86	0.85	0.84	0.84	0.83	0.82	0.81	0.80	0.79
Decks	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82
Painting	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91
Maintenance	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Guardrail	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Pavement Markings	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Drainage	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Signage	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Vegetation/Roadside	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Pavement Surfaces	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
Overall ASI	0.88	0.87	0.855	0.84	0.83	0.82	0.81	0.79	0.77	0.75

Each asset/program has its own sustainability index, which can be then be aggregated into an overall ASI for the agency. The agency can then analyze the specific asset(s)/program(s) that strongly impact the overall ASI. This can help the agency and policymakers set priorities as they make investment decisions. Such a performance metric can help track the financial sustainability of agency assets.

Glossary of Terms

GLOSSARY OF TERMS

The primary source of information for this glossary is the *AASHTO Transportation Asset Management Guide: A Focus on Implementation* (AASHTO 2011)

Asset: The physical transportation infrastructure (e.g. travel way, structures, other features and appurtenances, operations systems, and major elements thereof); more generally, can include the full range of resources capable of producing value-added for an agency: human resources, financial capacity, real estate, corporate information, equipment and materials, etc.; an individual, separately-managed component of the infrastructure (e.g. bridge deck, road section surface, streetlight).

Asset Management (AM): A strategic approach to managing transportation infrastructure. It focuses on business processes for resource allocation and utilization with the objective of better decision making based upon quality information and well-defined objectives.

Asset Management System: An integrated set of procedures, tools, software, and data intended to support proactive management decision making regarding the preservation, improvement, and replacement of assets.

Capital Investment: A type of investment that generally involves construction or major repair; includes the construction of new assets, reconstruction or replacement of existing assets, structural and functional improvements to existing assets, and rehabilitation of existing assets; when precision is required, capital refers to work that is funded under the agency's capital budget according to agency policy.

Deterioration Model: A mathematical model to predict the future condition of an asset or asset element, if no action, or only un-programmed maintenance, is performed.

Direct Costs: Costs of an agency activity that are directly related to the quantity of work (e.g. labor, material, equipment usage, contract pay items).

Equivalent Uniform Annual Cost (EUAC): Net present value, converted to an annuity (uniform annual monetary amount) or perpetuity.

Expected Outcomes: These are forecasted outcomes based on predictive modeling.

Gap Analysis: A tool for drilling down into the detail of the transportation asset management processes which uses the maturity model as its scale.

Health Index: Weighted average computed over the elements of an asset and a set of condition criteria, of the percent of each element that satisfies each criterion. It may be described by terms such as bridge condition rating or index, or pavement condition rating or index.

Indirect Costs: The cost of implementing a programmed activity, including direct and indirect costs. In capital budgeting analyses, initial cost is interpreted as the direct reduction in available budget as a result of a commitment to the activity.

Level of Service (LOS): Qualitative measures related to the public's perception of asset condition or of agency services; used to express current and target values for maintenance and operations activities.

Life Cycle: A length of time that spans the stages of asset construction, operation, maintenance, rehabilitation, and reconstruction or disposal/abandonment; when associated with analyses, refers to a length of time sufficient to span these several stages and to capture the costs, benefits, and long-term performance impacts of different investment options.

Life-Cycle Cost: Net present value (or equivalent uniform annual cost) of the sequence of monetary costs and benefits in a life-cycle activity profile. In the context of a life-cycle cost analysis, LCC should be defined as to the types of costs it includes; for example whether un-programmed maintenance or user costs (or both) are included, as well as inflationary assumptions about the cost stream.

Maturity Model: A concept used to specify the relative position of the agency for each transportation asset management process.

Performance: Characteristic of an asset that reflects its functionality or its serviceability as perceived by transportation users; may be related to condition.

Performance Gap: The gap between an asset's current condition/performance and a defined target or threshold value; implies need for work.

Performance Measure: An indicator, preferably quantitative, of service provided by the transportation system to users; the service may be gauged in several ways (e.g. quality of ride, efficiency and safety of traffic movements, services at rest areas, quality of system condition, etc.).

Periodic Maintenance: Maintenance or repair activity that is conducted on a fixed schedule according to manufacturer recommendations, research recommendations, or a maintenance intervention strategy (e.g. light bulb replacement, vehicle maintenance).

Plan Outcomes: These describe performance outcomes that are consistent with MnDOT financially constrained spending priorities. *Targets* and *Plan Outcomes* are not mutually exclusive.

Preservation: Actions to deter or correct deterioration of an asset to extend its useful life; does not entail structural or operational improvement of an existing asset beyond its originally designed strength or capacity.

Preventive Maintenance: Proactive maintenance approach that is applied while the asset is still in good condition; extends asset life by preventing the onset or growth (propagation) of distress.

Prioritization: Arrangement of investment candidates in descending order according to their importance to the agency mission (usually represented by an objective function or benefit measure) in relation to their initial cost.

Reactive Maintenance: Emergency or other un-programmed time-sensitive maintenance or repair that arises as a response to observed defects or performance problems (e.g. small bridge deck repairs, traffic signal repairs, incident response).

Rehabilitation: An event consisting of multiple treatments intended to correct physical or functional defects that impair the satisfaction of a level of service standard that the asset may previously have satisfied. It may include replacement of parts of the asset but not the entire asset, and is generally understood to be more significant in scale than a repair.

Repair: Treatment applied in order to correct a physical or functional defect that impairs the satisfaction of a level of service standard that the asset may previously have satisfied. Repairs are usually understood as intermediate in scale between maintenance and rehabilitation. Specific instances of repairs may be programmed or un-programmed according to agency policy.

Replacement: Disposal of an existing asset and substitution of a new asset serving the same functional requirements and possibly additional requirements in the same location; replacement-in-kind is a type of replacement where the new asset is substantially similar in function to the old asset, following the principle of modern engineering equivalence.

Risk (of an asset): The possibility of adverse consequences related to an asset from natural or man-made hazards. Generally consists of the likelihood of the hazard, the consequences of the hazard to the asset, and the impact of asset damage or malfunction on the mission of the asset or on life, property, or the environment.

Routine Maintenance: Un-programmed, non-urgent maintenance activities undertaken by crews that are scheduled on a daily, weekly, or monthly basis (e.g. street cleaning, drainage inspection and maintenance, bridge washing).

Strategic: A view of assets that is policy-based, performance-driven, long-term, and comprehensive.

Targets: A fixed benchmark against which MnDOT evaluates past, present, and future performance.