DEPARTMENT OF TRANSPORTATION

Transportation Asset Management Plan

June 2019

MinnesotaGO

A Collaborative Vision for Transportation

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DEPARTMENT OF TRANSPORTATION

395 John Ireland Blvd.
Saint Paul, MN 55155-1800

June 26, 2019

Mr. Wendall Meyer
Division Administrator
Federal Highway Administration – Minnesota Division
380 Jackson Street, Suite 500
St. Paul, MN 55101

Dear Mr. Meyer,

I am pleased to present Minnesota Department of Transportation's final Transportation Asset Management Plan (TAMP). Minnesota's 14,000 mile highway system – constructed, operated, managed, and maintained by the Minnesota Department of Transportation – 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-based management techniques since the mid-1990s and formally incorporated performance measures into our planning processes in 2003. The development of this risk-based TAMP represents an extension of MnDOT's commitment to efficiently managing the state's transportation assets.

This final TAMP is being submitted at this time to meet the requirements established through the Moving Ahead for Progress in the 21st Century Act and subsequent Federal rulemaking 23 CFR part 515. It is the result of a collaborative effort, guided by a Steering Committee with representation from a wide range of offices and districts, senior leadership, and the Federal Highway Administration – Minnesota Division staff. We particularly appreciate the support and guidance provided by the FHWA staff as we worked our way through this process and look forward to your final approval and certification.

Be assured that this asset management planning effort has already improved infrastructure management at the agency. Using the TAMP as a guide, MnDOT will continue to make progress towards implementation of recommended life cycle management strategies, risk mitigation strategies, asset condition performance targets, and investment strategies. The TAMP will serve as an accountability and communication tool and will inform established capital and operations planning efforts.

Sincerely,

Margaret Anderson Kelliher

Margaret Anderson-Kelliher
Commissioner

CC: Ryan Hixson, FHWA

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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 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.

On July 6, 2012, the Moving Ahead for Progress in the 21st Century Act was signed into law. MAP-21 required states to develop a risk-based transportation asset management plan for the National Highway System to improve and 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.[2] The legislation focused on the development of a TAMP for bridges and pavements on the NHS, but encouraged states to include other infrastructure assets within the right-of-way corridor. These requirements were continued in the Fixing America's Surface Transportation Act, enacted in 2015. MnDOT opted to include 12 asset classes, which is a subset of all MnDOT owned assets.

After the requirements for the TAMP were established in MAP-21, MnDOT was selected as a pilot state to develop a draft TAMP. The draft was completed in 2014 and shared publicly to help other states develop their TAMPs. Since then, MnDOT has expanded the number of assets included in asset management planning and made significant progress on the priority strategies in the draft TAMP. This document includes the work completed during the initial pilot project as well as subsequent additions and refinements.

What is Asset Management?

"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 replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost"

MAP-21 Federal Highway Administration

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

Purpose

The Minnesota Department of Transportation's Transportation Asset Management Plan will serve as an accountability and communication tool. It will also inform capital and operations planning efforts. In addition to being a federal requirement, the TAMP is a planning tool to help MnDOT further evaluate risks, develop mitigation strategies, analyze life cycle costs, establish asset condition performance measures and targets, and develop investment strategies. The TAMP formalizes and documents the following key information to meet federal requirements:

- 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 that considers 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 use existing assets
- Develop an unbiased methodology to balance trade-offs between competing objectives

Figure 1-2: Minnesota's State Highway System

TAMP Development Process

MnDOT was one of three pilot states to create a TAMP, which was completed in 2014. This initial plan was completed with coordination between MnDOT, a consultant, and the Federal Highway Administration. Pavements, bridges, culverts, deep stormwater tunnels, overhead sign structures, and high-mast light tower structures on the entire state highway system (see Figure 1-2) were included.

After completion of the pilot TAMP, FHWA released a final rule on transportation asset management plans titled "Asset Management Plans and Periodic Evaluations of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events" 23 CFR Parts 515 and 667 on October 24, 2016. MnDOT developed a draft TAMP to meet these requirements, adding six additional asset classes:

- Noise Walls
- Signals
- Lighting
- Pedestrian Infrastructure
- Buildings
- Intelligent Transportation Systems

The draft TAMP was completed and submitted to FHWA in April 2018. It met all federal requirements, receiving full certification. This final TAMP was completed and submitted to FHWA in June 2019. All TAMP development went through the same process that involved internal staff from asset-expert work groups, a project management team, a TAMP Advisory Group, and an Asset Management Steering Committee.

Asset-expert work groups were developed for broad asset categories: pavement, bridge, culverts and deep stormwater tunnels, overhead sign structures and high-mast light tower structures, noise walls, signals and lighting, pedestrian infrastructure, buildings, and ITS. Each was composed of subject matter technical experts and included at least one representative from a greater Minnesota district. These experts were integral in documenting current practices, determining data availability, assessing risks and proposing mitigation strategies, and identifying targets and investment strategies.

The TAMP project management team included experts from MnDOT's Statewide Planning and Asset Management Program offices. The purpose of this team was to provide strategic direction throughout the day-to-day TAMP work activities, focusing on process.

MnDOT's TAMP Advisory Group coordinates and communicates asset management planning across the agency, particularly to district staff. This group convenes on an as-needed basis to provide decision-making from a cross-asset perspective.

Finally, MnDOT's Asset Management Steering Committee provides high-level direction and oversight during TAMP development as well as all broad agency asset management activities. This committee includes broad representation across the agency and from Minnesota's FHWA division office.

The final TAMP includes federally required pavement and bridge assets. MnDOT also opted to include 10 additional assets, categorized as other assets, which include asset sub-groups.

Required Assets:

- Pavements
- Bridges (Including Large Culverts)

Other Assets:

- Highway Culverts
- Deep Stormwater Tunnels
- Overhead Sign Structures
- High-Mast Light Towers
- Noise Walls
- Traffic Signals
- Lighting
- Pedestrian Infrastructure (Curb Ramps and Sidewalks)
- Buildings (Rest Areas, Weigh Stations/Scales, Small and Medium Truck Stations, Large Truck Stations, Salt Sheds, Storage Sheds, Office Buildings, and Miscellaneous Buildings)
- Intelligent Transportation Systems (Fiber Communication Network, Fiber Network Shelters, Traffic Management System Cabinet, Dynamic Message Signs, Traffic Monitoring Cameras, Traffic Detector Stations/Site-Loops and Radar, Various Communication Equipment, MnPASS Readers, Reversible Road Gates, Ramp Meters, Rural Intersection Conflict Warning Systems, Road Weather Information Systems Sites, Automatic Traffic Recorders, Weigh-In-Motion System Sites, Road Closure Systems)

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 or are currently being implemented. For example, MnDOT is in the process of implementing an Enterprise Asset Management Software called MnDOT's Transportation Asset Management System that will allow the agency to better manage roadside infrastructure data, including 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., Minnesota 20-Year State Highway Investment Plan). The intent of the TAMP is to build upon and enhance, but not supplant, established planning processes.

- **Improve Data Management.** 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 direction 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, planning, and programming at MnDOT to the TAMP.
- Chapter 3: Asset Management Performance Measures and Targets – This chapter summarizes MnDOT's performance measures and asset targets as well as the required federal measures and targets.
- Chapter 4: Asset Inventory and Condition – This chapter summarizes information about all 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, risks associated with undermanaging transportation assets, and strategies to mitigate these risks.
- Chapter 6: Life Cycle Planning – This chapter describes life cycle planning and highlights strategies for managing assets. It includes a cost-effectiveness comparison of approaches to managing each asset.
- Chapter 7: Performance Gaps – This chapter highlights state and federal performance measures and targets and identifies 10-year expected outcomes for the state measures.
- 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 TAMP process beginning with the pilot. This chapter also identifies implementation steps to continually make progress toward better asset management and presents recommendations for future updates to the TAMP.

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Chapter 2

ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK

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ASSET MANAGEMENT OBJECTIVES

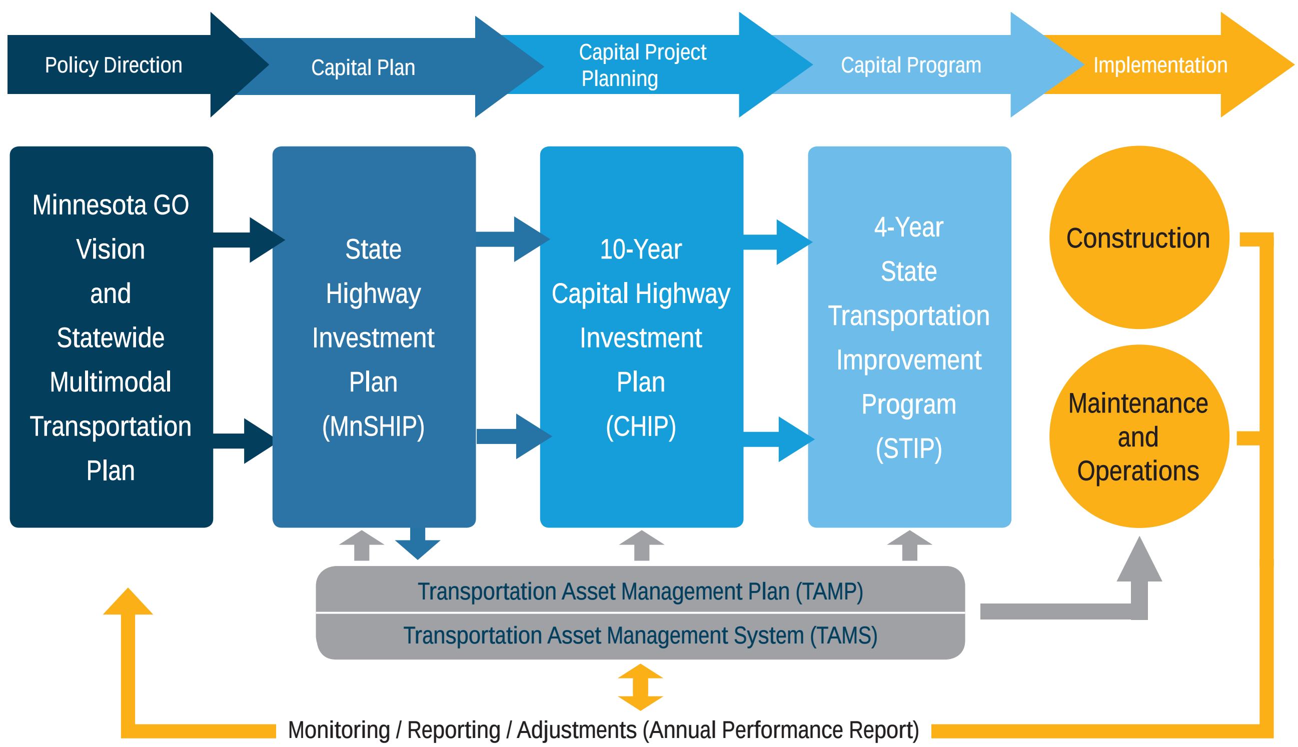
Overview

MnDOT has strong business processes in place to prioritize asset management investments in Minnesota's transportation infrastructure. MnDOT asset management guides the effective use of available resources to make the right investment decisions and minimize asset life cycle costs, while considering the various trade-offs 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 key transportation asset management objectives include the following:

- Achieve performance targets
- Minimize life-cycle costs
- Integrate maintenance and capital investments
- Consider risk in decision making
- Make informed tradeoff decisions
- Use quality data to drive decisions

Additional priorities and objectives are reflected in MnDOT's investment plans, which include the 20-year State Highway Investment Plan for capital improvements. MnSHIP is 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 – to improvements made on the state highway system.

MnSHIP documents the investment strategies and expected outcomes for all capital investment categories including asset management. The pilot TAMP, completed in 2014, served as a supporting document informing the investment trade-off decision reflected in the 2018-2037 MnSHIP. Performance measures and targets as well as investment strategies in the pilot TAMP were incorporated into the updated MnSHIP. The TAMP does not replace any existing MnDOT plan; rather, it provides critical input to existing plans by better linking capital and maintenance expenditures related to asset preservation.

MnDOT will use the TAMP to more thoroughly analyze life cycle costs, evaluate risks and develop mitigation strategies, establish asset condition performance measures and targets, and develop investment strategies. The objective is to manage assets to the lowest life cycle cost while delivering an agreed upon level of service (i.e., performance). The TAMP will serve as an accountability and communication tool and will inform established capital and operations planning efforts.

Existing Asset Management Planning

MINNESOTA GO VISION

MnDOT's long-term (50-year) vision is to create a multimodal transportation system that maximizes the health of people, the environment and Minnesota's economy. 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 shown in Figure 2-2.

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

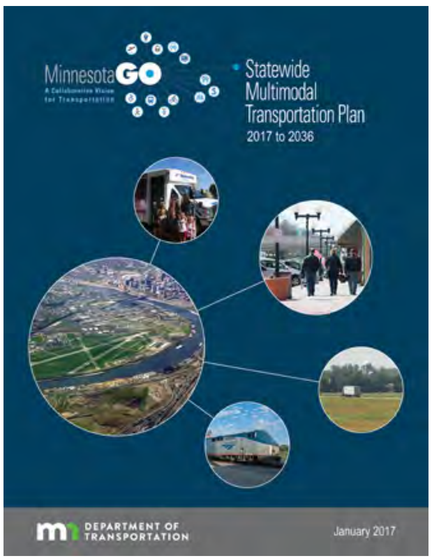
GUIDING PRINCIPLES	GUIDING PRINCIPLE STATEMENTS
Leverage Public Investments to Achieve Multiple Purposes	Provide a transportation system to support other public purposes such as environmental stewardship, economic competitiveness, public health, and energy
Ensure Accessibility	Provide a safe system for user of all abilities and incomes
Ensure Accessibility	Provide access to key resources and amenities
Build to a Maintainable Scale	Consider and minimize long-term obligations
Build to a Maintainable Scale	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, adopted in 2017, 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 below, stress the importance of data in strategically operating and maintaining the transportation system.

Open Decision-Making

Make transportation system decisions through processes that are inclusive, engaging, and supported by data and analysis. Provide for and support coordination, collaboration, and innovation. Ensure efficient and effective use of resources.



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

Transportation Safety

Safeguard transportation users and the communities through which the system travels. Apply proven strategies to reduce fatalities and serious injuries for all modes. Foster a culture of transportation safety in Minnesota.

Critical Connections

Maintain and improve multimodal transportation connections essential for Minnesotans' prosperity and quality of life. Strategically consider new connections that help meet performance targets and maximize social, economic and environmental benefits.

Healthy Communities

Make fiscally responsible transportation system decisions that respect and complement the natural, cultural, social, and economic context. Integrate land use and transportation to leverage public and private investments.

System Stewardship

Strategically build, manage, maintain, and operate all transportation assets. Rely on system data and analysis, performance measures and targets, agency and partners' needs, and public expectations to inform decisions. Use technology and innovation to get the most out of investment and maintain system performance. Increase the resiliency of transportation system and adapt to changing needs.

System Stewardship includes asset management as one of three concepts addressed under the objective area. Asset management related strategies under System Stewardship include:

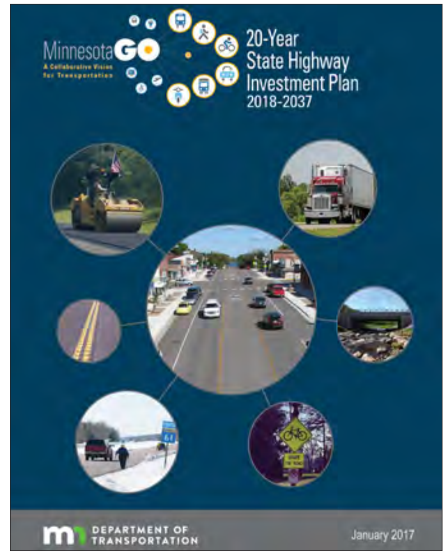
- Give asset management priority to infrastructure on identified priority networks
- Maximize the useful life of transportation assets while considering system performance, costs and impacts to the state's economy, environment, and quality of life
- Incorporate asset management principles into capital, maintenance, and operations decisions

STATE HIGHWAY INVESTMENT PLAN

MnDOT documents its capital investment strategies to address all five of the above SMTP objectives in the State Highway Investment Plan. MnSHIP is a 20-year plan that 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 2018-2037 plan predicts revenues for the next 20 years to total $21 billion, although the projected needs on the transportation system total $39 billion. This $18 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.

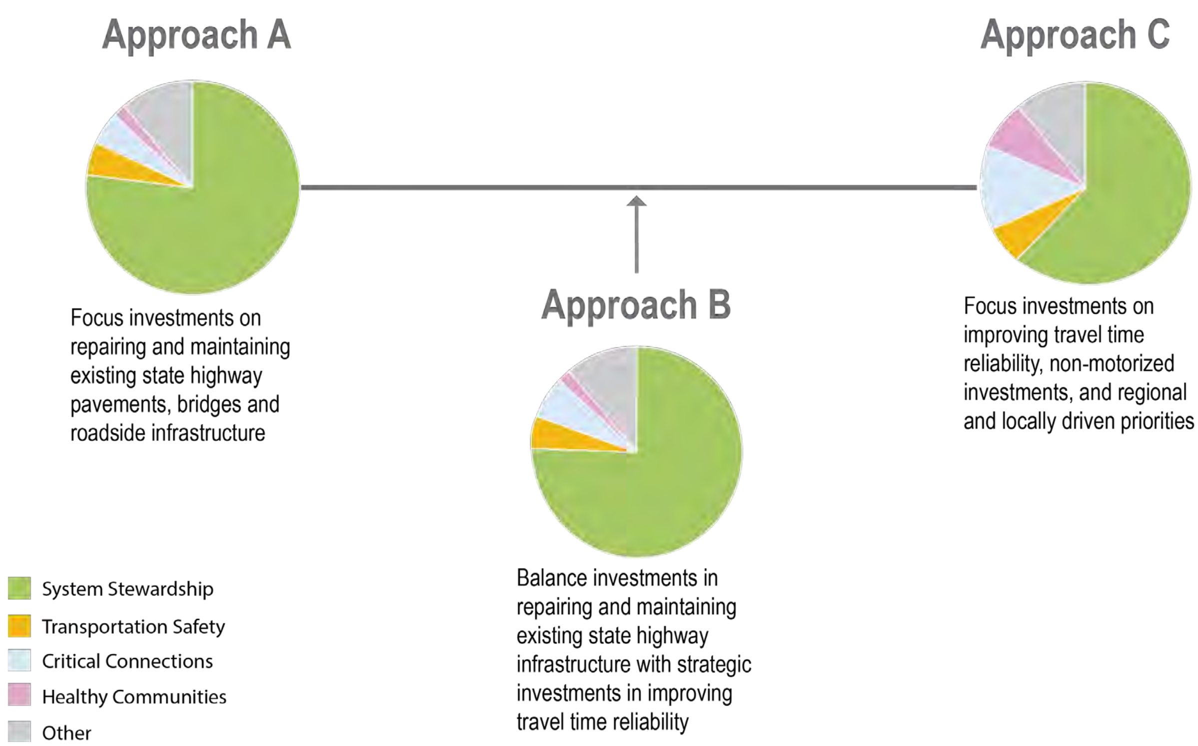
The growing disparity between available resources and the investments needed to maintain the transportation infrastructure system at a desired level of service has been the guiding focus for the major themes identified during the development of the TAMP (discussed in Chapter 1). These themes include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

The use of a performance-based approach to inform investment and project decisions is not a new concept for MnDOT. During the MnSHIP development process, trade-offs between investment levels, performance levels and risks were evaluated to improve understanding of the impact of investment decisions through a more holistic approach. Figure 2-3 summarizes three approaches developed during the MnSHIP scenario planning process.



MnSHIP directs $6.1 billion to be spent on Asset Management over the next 20 years.

Figure 2-3: Investment Approaches Developed for Scenario Planning



MnDOT developed the three approaches to demonstrate a range of objectives to pursue over the next two decades, as well as to evaluate the trade-offs in performance and risk management within each approach. To illustrate these trade-off decisions, MnDOT developed performance levels for each investment category and then packaged different performance levels from each category into three investment approaches. Internal and external feedback on these trade-offs was considered in the development of the investment direction in MnSHIP.

The final MnSHIP investment direction and investment strategies are discussed in more detail in Chapter 8: Financial Plan and Investment Strategies.

The 10-Year Capital Highway Investment Plan is updated annually to communicate MnDOT's proposed capital investments for the next 10 years.

CAPITAL HIGHWAY INVESTMENT PLAN

The 10-year Capital Highway Investment Plan is updated each year to communicate MnDOT's proposed capital investments for the next 10 years, serving as an annual check-in between the MnSHIP plan update cycles. It provides the opportunity to track investments compared to the investment guidance established in MnSHIP, ensuring accountability. The primary objectives of the CHIP are to:

- Detail MnDOT capital investments over the next 10 years on the state highway network
- Compare planned and programmed projects with the investment priorities established in MnSHIP, and explain any change in direction or outcomes
- Facilitate coordination between MnDOT districts and local units of government on future investments
- Improve the transparency of MnDOT's proposed capital investment and decision-making

Selecting projects on the state highway system is an annual process. MnDOT starts identifying potential projects 10 years in advance. MnDOT district staff work each year with MnDOT central office and specialty office staff to complete a 10-year list of projects for each district on the state highway system. MnDOT then combines the districts project lists into the 10-Year Capital Highway Investment Plan.

MNSHIP CAPITAL INVESTMENT PRIORITIES

With the recent update of MnSHIP, the 20-year investment direction shifted focus to maintaining the existing state highway system while making limited mobility investments. It continues a shift for MnDOT from being a builder of the system to being the maintainer and operator of the system. The investment direction does not affect the projects already developed and programmed in years 2018 through 2021. Projects in those years were based on the 2013

MnSHIP investment direction which took a more balanced approach between asset management and mobility investments. The priorities identified in the current plan will be reflected in investments and projects starting in 2022. 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. Figures 2-4 through 2-7 summarize the specific strategies that MnDOT identified as a part of the MnSHIP and TAMP development processes to better manage performance in various capital program areas over the next 20 years. The TAMP focuses specifically on the strategies within the System Stewardship objective area.

Figure 2-4: System Stewardship Capital Strategies for More Efficient Asset Investments

INVESTMENT CATEGORY	SYSTEM INVESTMENT STRATEGY
Pavement Condition	Optimize investment at the network level with a mix of strategies considering the lowest life cycle cost
Pavement Condition	Prioritize investment to maintain conditions on NHS pavements
Pavement Condition	Allow non-NHS pavements to deteriorate to a slightly lower condition, while maintaining safe conditions for the traveling public
Pavement Condition	Focus on reactive maintenance activities (e.g., pothole patching) to avoid hazardous conditions
Pavement Condition	Use operational budget for maintenance of pavements
Pavement Condition	Apply short-term fixes to address immediate needs
Pavement Condition	Develop new materials, design standards and procedures
Pavement Condition	Use recycled materials, innovative design, and preventive maintenance treatments to extend the useful life of infrastructure without increasing costs
Pavement Condition	Plan for two comparable repair strategies (concrete versus bituminous) for some projects so contractors can bid the most cost-effective solution
Bridge Condition	Invest to meet NHS and non-NHS bridge condition targets
Bridge Condition	Invest in state highway bridges at optimum points in their life cycles to ensure safety and structural health
Bridge Condition	Conduct bridge inspections to ensure timely application of maintenance, capital improvements, public safety, and structural integrity
Bridge Condition	Apply appropriate measures to ensure bridges achieve or exceed their intended service lives
Bridge Condition	Research/evaluate innovative materials and construction techniques
Roadside Infrastructure Condition	Repair and replace infrastructure in poor condition or infrastructure beyond its service life
Roadside Infrastructure Condition	Replace infrastructure with the greatest exposure to the traveling public, mostly through pavement/bridge projects
Jurisdictional Transfer	Commit to correcting roads with the highest degree of mismatched ownership (i.e., those identified in Track 0 of the 2014 Minnesota Jurisdictional Realignment Project report)
Jurisdictional Transfer	Balance investment between the Twin Cities area and Greater Minnesota
Jurisdictional Transfer	Identify projects in the CHIP where investments could facilitate the transfer of ownership
Facilities	Prioritize health and safety-related repairs to rest areas unless replacement is warranted
Facilities	Focus investments on weigh scale mechanics and existing weigh station buildings

Figure 2-5: Transportation Safety Capital Strategies for More Efficient Asset Investments

INVESTMENT CATEGORY	SYSTEM INVESTMENT STRATEGY
Traveler Safety	Invest in high priority, lower cost proactive projects
Traveler Safety	Install lighting at high-crash locations

Figure 2-6: Critical Connections Capital Strategies for More Efficient Asset Investments

INVESTMENT CATEGORY	SYSTEM INVESTMENT STRATEGY
Twin Cities Mobility	Focus on investments that provide reliable congestion-free options on Twin Cities metro area corridors
Twin Cities Mobility	Focus on low cost spot mobility projects that provide safety benefits and reduce delays
Greater Minnesota Mobility	Focus investment to improve travel time reliability through operational improvements such as upgraded traffic signals, ITS, turn lanes and passing lanes
Freight	Explore system investment strategies for the Freight Investment category in the Freight Investment Plan
Bicycle Infrastructure	Focus 70% of bicycle investments in urban areas and 30% of investments in rural areas
Bicycle Infrastructure	Add to existing bridge and pavement projects to improve safety and connectivity of the state bikeway system
Accessible Pedestrian Infrastructure	Focus more investment in sidewalk, curb ramp and accessible pedestrian signal projects
Accessible Pedestrian Infrastructure	Make other pedestrian improvements via complete streets and complete gaps in the network

Figure 2-7: Healthy Communities Capital Strategies for More Efficient Asset Investments

INVESTMENT CATEGORY	SYSTEM INVESTMENT STRATEGY
Regional and Community Improvement Priorities	Invest in economic development-driven projects through the Transportation Economic Development program
Regional and Community Improvement Priorities	Expand partnerships with local agencies/communities that leverage funds to complete larger projects

Existing Asset Management Programming Framework

Once investment levels are set, projects are selected to help achieve the targeted performance expectations established by MnDOT. This TAMP was developed using several tools available to help determine the best use of available funding for asset management activities. These tools include advanced systems that meet the federal standards for analyzing bridge and pavement conditions.

Planned and programmed projects are based on recommendations from the management systems and input from MnDOT districts. MnDOT district staff work each year with MnDOT central office and specialty office staff to complete a 10-year list of projects for each district on the state highway system. MnDOT then combines the districts' project lists into the 10-Year Capital Highway Investment Plan.

The CHIP includes projects in two time periods:

- Years 5-10 represent MnDOT's planned projects
- Years 1-4 represent projects MnDOT selected for funding and committed to delivering, which are included in the State Transportation Improvement Program

Annual work plans for needed maintenance and operations activities are then derived from the STIP and CHIP.

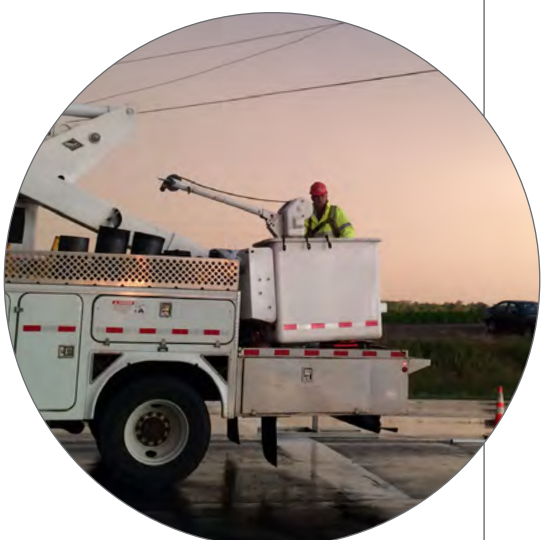
HIGHWAY PAVEMENT MANAGEMENT APPLICATION

MnDOT manages pavement condition data through its Highway Pavement Management Application software developed by Stantec Consulting, which meets all federal minimum standards for developing and operating pavement management systems pursuant to 23 U.S.C.150 (c)(3)(A)(i). 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 given funding constraints. The dynamic application allows for comparisons between a range of treatment option scenarios, from "minimum maintenance only" to "full reconstruction." This process is explained further in Chapter 8: Financial Plan and Investment Strategies.

MnDOT's roadway network is kept up to date using ESRI's Roads and Highways database management system. This ORACLE-based application allows for the roadway and bridge network to be kept current and is used as a basis for the pavement network for HPMA modeling.

The condition of the network is measured annually by MnDOT's pavement management unit using a special digital inspection vehicle equipped with an inertial profiler, 3D laser camera system, digital video imaging system and GPS antenna. All state highways (includes interstate routes) are driven in both directions annually with this vehicle. In addition, any NHS route that is not part of the state highway system (see **figure 2-8**) is also driven. Once driven, the data is processed to calculate roughness, rutting, faulting, and cracking. The state highway data is stored in MnDOT's pavement management system. HPMA stores all of the historical pavement condition information. While the non-state NHS routes are processed outside of HPMA, they are reported as part of the official HPMS submittal to FHWA and incorporated into the NHS pavement conditions.

MnDOT has legacy processes in place to update the HPMA data in response to the completion of construction projects and this effort captures substantive capital project work. MnDOT is also developing its TAMS system in a way that will capture relevant work performed by its maintenance crews (such as crack sealing and seal coating) and make it available for incorporation into the HPMA data as may be appropriate. Finally, MnDOT routinely uses indefinite delivery, indefinite quantity contracting methods to perform preventive maintenance and other activities. In 2019, MnDOT will add functionality to its Capital Highway Information Management Enterprise System and develop business processes that will allow for more formal tracking of this type of work and make the pavement data as complete as possible.

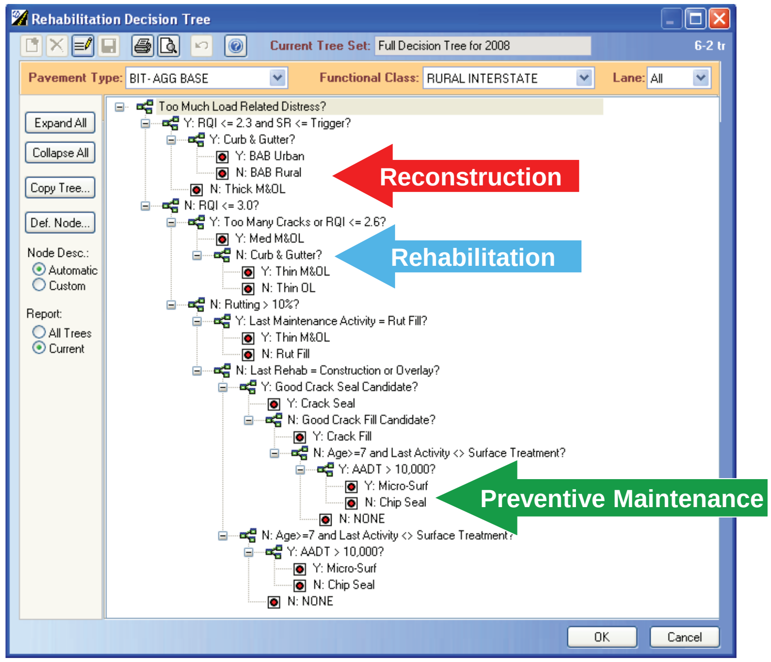


Each segment of road in HPMA has its own deterioration curve, used for predicting future conditions. There is a deterioration curve for roughness and cracking. If there is enough historical data for the segment, HPMA will do a regression fit through all the data collected since the last major rehabilitation. If the resulting curve meets certain quality requirements, it will be used. If not, a default curve, based on the deterioration of similar roads will be used. Each segment of road in HPMA has predicted conditions 50 years beyond the current condition. Future planned projects can be loaded into the system which will then modify the predicted conditions to reflect the improved conditions based on the planned fix.

Figure 2-8: NHS Pavement Segments Owned By Local Agencies

OWNER	ROUTE	STREET NAME	CENTERLINE MILES
Anoka County	CSAH 14	Main St.	13.4
Dakota County	CSAH 23	Cedar Ave.	1.3
Dakota County	CSAH 32	Cliff Rd.	2.1
Dakota County	CSAH 42	145th St. E.	17.4
Hennepin County	CSAH 81	Main St.	0.1
Hennepin County	CSAH 152	Cedar Ave. S	0.4
Hennepin County	CSAH 153	Lowry Ave. N	0.9
Olmsted County	CSAH 16	N/A	0.9
Ramsey County	CSAH 36	Warner Rd.	2.4
Ramsey County	CSAH 37	Shepard Rd.	2.2
Scott County	CSAH 21	Crest Ave.	3.6
Scott County	CSAH 42	140th St.	5.5
Stearns County	CSAH 75	Division St.	13.8
Saint Louis County	CSAH 91	Haines Rd.	1.5
City of Duluth	MSAS 140	N Lake Ave.	0.1
City of Duluth	MSAS 149	Garfield Ave.	0.9
City of Duluth	MSAS 171	W. Superior St.	0.7
City of East Grand Forks	MSAS 120	Central Ave.	0.5
City of Minneapolis	MSAS 169	Dowling Ave. N.	0.1
City of Minneapolis	MSAS 215	2nd St. N.	0.6
City of Rochester	MSAS 201	S. Broadway Ave.	0.1
City of Saint Paul	MSAS 194	W. Shepard Rd.	0.1
City of Saint Paul	MSAS 249	W. Shepard Rd.	0.1
City of Willmar	MSAS 153	1st St. NE	4.5
City of Duluth	N/A	Port Terminal Rd.	0.6
City of Duluth	N/A	Port Terminal Rd.	0.4
City of Minneapolis	N/A	32nd Ave.	0.1
City of Minneapolis	N/A	30th Ave. NE	0.1
City of Minneapolis	N/A	E Frontage Rd.	0.2
U.S. Military	N/A	Infantry Rd.	0 (driveway)
Metropolitan Airports Commission	N/A	Glumack Dr.	1.7
Metropolitan Airports Commission	N/A	Glumack Dr.	0.5
TOTAL MILEAGE	N/A	N/A	76.8

Figure 2-9: HPMA Decision Tree



Risks associated with HPMA were evaluated and identified in MnDOT's risk register. A conceptual model of HPMA is shown in Figure 2-9.

When maintenance and rehabilitation analysis is done, each section of road goes through a decision tree. The decision tree identifies a fix based on the predicted condition, age, traffic, etc., for each year of the analysis period. Once a treatment is identified, the default curve for the recommended treatment is applied and the area between that curve and the "do nothing" curve is calculated. This area is then multiplied by an effectiveness factor based on the section length and traffic volume. The cost of the recommended fix is also calculated. The effectiveness of the fix is divided by the cost of the fix to generate the Cost-Effectiveness. A matrix of all possible treatments, their effectiveness, cost and cost-effectiveness is built.

Once the matrix of possible treatments is developed, constraint sets are created identifying the available budgets and/or desired conditions. If only desired conditions are identified, the analysis will determine the funding needed to meet them. If only a budget is identified, the analysis will determine the best conditions achievable. If both are identified, the analysis will select projects that most cost-effectively achieve the desired conditions for the available budget. Analysis can be done for as little as one year or as long as 30 years.

HPMA uses a near optimal technique known as Marginal Cost Effectiveness when selecting projects. The MCE process begins by selecting the section/treatment with the highest cost-effectiveness. The MCE is then calculated for all other possible treatments for that same section. The MCE value replaces the initial cost-effectiveness value for those treatments.

MCE is defined as:

MCE=(Er-Es)/(Cr-Cs)

Where Er= Effectiveness of alternative

Es= Effectiveness of selected treatment

Cr= Cost of alternative

Cs= Cost of currently selected treatment

The process then moves on to the section/treatment with the next highest cost-effectiveness. Again, the MCE is calculated for all other possible treatments for that same section. After each selection, the cost of selected treatments is checked against the budget and the resulting network condition is checked against the desired conditions. If either is met, the analysis moves to the next year. If not, the MCE process continues, selecting and exchanging projects. The MCE process results in the combination of projects that yield the highest cumulative effectiveness over the network for a given budget.

Each year, the analysis described above is done. The projects in the current STIP, plus any preventive maintenance set-asides are assumed. The result of the analysis is a set of recommended projects, their anticipated cost, and expected impact on the condition of the network. This process is repeated under financial constraints during the preparation of MnSHIP investment scenarios yielding the most cost effective investment strategy for a given funding level. Under the direction of the Minnesota Legislature, MnDOT adopted a new Project Selection Policy in November 2018. The policy added a formal scoring methodology to the pavement project selection process.

BRIDGE REPLACEMENT AND IMPROVEMENT MANAGEMENT SYSTEM

MnDOT follows the National Bridge Inspection Standards, the Specification for the National Bridge Inventory Bridge Elements, and the MnDOT Bridge and Structure Inspection Program Manual for requirements surrounding the collection of bridge data. MnDOT's Bridge Replacement and Improvement Management System follows all federal minimum standards for developing and operating a bridge management system pursuant to 23 U.S.C.150(c)(3)(A)(i), but also expands the effort to provide additional value in areas that MnDOT deems necessary.

Minnesota requires all inspection reports to follow an electronic workflow, so that each inspection type must follow an appropriate line of approvals. Any report that changes bridge conditions must be reviewed and electronically signed by a Registered Professional Engineer. All reports in Minnesota are subject to compliance reviews by Minnesota's data-driven compliance review process.

Minnesota uses Bentley InspectTech, rebranded SIMS, as the interface to collect bridge inventory and inspection data, including NHS bridges owned by other agencies (see Figure 2-10). Minnesota then copies this data back into MnDOT databases through two separate data flows:

1) To support the customized reporting and analysis tools.

2) To support the use of AASHTOWare BrM, which is currently updated to version 6.0, the latest release.

Minnesota maintains currency of bridge data through the required inspection frequencies. Minnesota allows inspectors to make updates to the information in advance of the inspection due date in Update Report in SIMS. Minnesota also makes bulk updates to inventory information through a controlled process in the MnDOT Bridge Inventory Management Unit.

BRIM is used for forecasting future bridge condition. BRIM uses a deterministic deterioration model developed from research that studied historical MnDOT deck NBI inspection data. There are seven deterioration curves that are based on district, AADT, superstructure type, and deck features, such as rebar type, wearing surface type, and depth of cover. A deterioration curve is assigned to each bridge and is used to forecast future condition taking into account improvement from future projects in MnDOT's four-year STIP and 10-year CHIP.

MnDOT does not formally determine the benefit-cost ratio of alternatives for each bridge. However, life cycle cost principles are built into the work type logic of BRIM and the repair strategies outlined in the Bridge Preservation and Improvement Guidelines. The treatment logic in BRIM provides a recommended work type, timeframe, and cost for each bridge. The treatment options include a mixture of preservation, rehabilitation, and replacement alternatives that consider the remaining life in the bridge. The timings of these treatments are based on condition and predicted deterioration. The output is reviewed annually by bridge experts in the districts and Bridge Office. The treatment logic can be varied to compare various repair strategies. The BRIM work type logic and deterioration modelling assumes that routine preventive maintenance treatments are being performed with frequencies established in the Bridge Maintenance Manual.

The treatment logic in BRIM also considers factors such as bridge width, vertical clearance, design live load, and historical design details. It is difficult to assign a monetary value to these factors to be able to include them in a traditional benefit cost analysis. However, these factors are important in the planning process. MnDOT is currently developing a life cycle cost model to validate the treatment rules within BRIM and the BPIG to more formally address alternatives by cost in addition to condition and the other factors noted above. MnDOT will consider incorporating this analysis in its planning process as experience with the life cycle cost model and various assumptions grows.

Figure 2-10: NHS Bridges Owned By Local Agencies

OWNER	INSPECTION AGENCY	LOCATION
County Highway Agency	Anoka County	Main St. over Coon Creek
County Highway Agency	Anoka County	Main St. NW over ditch
County Highway Agency	Anoka County	CSAH 14 over BNSF railroad
County Highway Agency	Anoka County	CSAH 14 over ped trail
Local Park/Forest	Metro District	TH 65 over ped trail
County Highway Agency	Dakota County	CSAH 42 over CP railroad
County Highway Agency	Hennepin County	CSAH 153 over Mississippi River
City or Municipal Highway Agency	Metro District	I 35W over ped trail
City or Municipal Highway Agency	Metro District	US 169 over ped trail
Railroad	Minnesota Dakota & Western Railroad	US 53 NB over Rainy River
City or Municipal Highway Agency	District 8	TH 23 over ditch
City or Municipal Highway Agency	District 8	TH 23 over ped trail
City or Municipal Highway Agency	City of St. Paul	MSAS 194(EB Shepard Rd.) over Koch Oil
City or Municipal Highway Agency	City of St. Paul	MSAS 194(WB Shepard Rd.) over Koch Oil
City or Municipal Highway Agency	City of St. Paul	MSAS 194 (Shepard Rd.) over Texaco Oil
County Highway Agency	City of St. Paul	CSAH 36(WB WARNER) over railroad
County Highway Agency	City of St. Paul	Shepard Rd over UP railroad
City or Municipal Highway Agency	City of St. Paul	Shepard Rd (CSAH37) over sewer
County Highway Agency	City of St. Paul	CSAH 36 over railroad
City or Municipal Highway Agency	District 6	TH 3 over TH 3 trail
County Highway Agency	Stearns County	CSAH 75 over Sauk River
City or Municipal Highway Agency	City of Duluth	W Superior St. over library tunnel
County Highway Agency	Stearns County	CSAH 75 over BNSF railroad
Private	District 3	TH 23 over Quarry Rd.
County Highway Agency	District 3	TH 23 over ditch
Railroad	Minnesota Dakota & Western Railroad	US 53 SB over Rainy River
Private	District 1	TH 61 over conveyor tunnel
City or Municipal Highway Agency	City of Willmar	MSAS 153 over ditch
County Highway Agency	Scott County	EGAN DR over Credit River

MnDOT has also developed a network level life cycle cost analysis that uses probabilistic deterioration modelling with Markov Chain analysis. This model can be used to compare investment scenarios and prioritize bridge investments by treatment category (i.e., preservation, rehabilitation, and replacement). This model currently relies on engineering judgment for the deterioration transition probabilities and resulting condition after a treatment. MnDOT will continue to develop this model with a goal of calibrating with historic condition data so that the model is data-driven. MnDOT is participating in a pooled fund study with other Midwest states that will provide additional deterioration modeling capabilities. MnDOT will consider more formally incorporating this network level LCCA in its planning process once it becomes a data-driven model.

The treatment logic within BRIM recommends a work type and timeframe based on deck condition, AADT, bridge deck type, and historical policies for design and materials. Unit costs are then applied to each bridge based on the recommended work type and bridge quantities. The results are used to develop short-term budget needs for the STIP and CHIP as well as long-term budget needs for the MnSHIP 20-year plan.

BRIM provides a candidate list of projects and the ability to forecast future condition of the system based on varying investment amounts. The treatment logic can be modified to compare multiple preservation strategies. The BPIG provides guidance on cost-effective repair strategies to be used during the scoping phase of a project.

The BRIM output is used for the development of the four-year STIP and 10-year CHIP. In addition to the treatment logic and deterioration modelling, BRIM also includes a risk assessment called the Bridge Planning Index. The BPI logic includes eight risk factors that determine the probability of a service interruption as well as four factors that create an importance factor. All of this information is used to create candidate lists of bridge projects by the districts.

Additional guidance for projects is provided by the BPIG and is applied during the scoping phase of a project. The results of the BRIM model provide a starting point, but there is no substitute for the scoping work that is performed on each bridge to determine the right repair. This includes a review of inspections, load rating analysis, review of geometric and safety features, review of problematic design details from the past, risk assessment, historical maintenance needs, current condition and predicted future condition, etc. All of this information is used in scoping to make the right decision for each bridge.

The bridge work is also reviewed to ensure it fits within the goals of the project and the corridor. Preservation work is typically packaged with multiple bridges to provide an economy of scale and to realize traffic control savings. In addition, bridge work is often packaged with adjacent pavement treatments to reduce traffic impacts along a corridor. The end result is a program that includes a mixture of bridge replacement, rehabilitation, and major preservation projects that considers the needs of other assets along the corridor.

TRANSPORTATION ASSET MANAGEMENT SYSTEM

MnDOT created the Asset Management Program Office whose function includes provision of data and implementation of software systems for asset management. Acquiring and maintaining data requires involvement of personnel from across the department, and it is one of the roles of this team to build that collaboration. This system, branded TAMS, houses the majority of MnDOT's non-pavement/bridge asset management inventory and condition information. TAMS now houses data for all of MnDOT's signals, lighting and ITS devices, traffic barrier infrastructure, non-bridge hydraulics infrastructure, noise walls, pavement markings, and signs. As of July 1, 2019, this system will be used to capture MnDOT maintenance staff labor, equipment and materials investments in maintaining these asset classes.

At its most basic level of use, TAMS allows reporting and mapping of asset data and historical maintenance expenditures. This information is used to create cost models for use in life cycle cost evaluations and maintenance demand estimates as well as evaluating performance. It is also useful in improving project scoping efficiency and effectiveness. The Traffic Signals and ITS module within TAMS allows for advanced analytics, though MnDOT is in the early stages of capitalizing on this functionality. MnDOT also has prepared a fairly robust decision tree for highway culvert maintenance and these algorithms are programmed into TAMS allowing for network needs analysis and work planning efforts.

TAMS is also used to maintain and update inventory information through the use of work orders, and other means such as condition inspections. MnDOT has acquired inventory and condition data for the assets mentioned above. The department is committed to maintaining the accuracy of the data through the use of TAMS, as well as the development of processes to capture as-constructed information and make updates to the stored data. This, too, requires collaboration between disciplines, building an appreciation for the various roles as well as an understanding of the use of the data by multiple users. Efforts from capital planning, project scoping, and asset to field work management will benefit from consistent and available data.

OTHER ASSET MANAGEMENT SYSTEMS

Buildings

ARCHIBUS software tracks all of MnDOT-owned building assets besides radio equipment buildings and buildings for traffic management systems. The state of Minnesota – Department of Administration has mandated that all state agencies maintain their building inventories for which they have custodial control and ensure that the floorplan drawings of those buildings and ARCHIBUS meets these requirements. There are two other mandated uses of ARCHIBUS. First, all data from the required Facility Condition Assessments is to be entered annually into the Capital Project Management Module. This data is required in order for the agency to receive Capital Investment Appropriations. Second, all leases between the state of Minnesota and a private or public entity and all leases between state agencies are entered and maintained in the Real Estate Portfolio Management Module.

Pedestrian Infrastructure

The Americans with Disabilities Act, enacted on July 26, 1990, is a civil rights law prohibiting discrimination against individuals on the basis of disability. Title II of the ADA pertains to the programs, activities, and services public entities provide. As a provider of public transportation services and programs, MnDOT must comply with this section of the Act as it specifically applies to state public service agencies and state transportation agencies. Title II of the ADA provides that, "…no qualified individual with a disability shall, by reason of such disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of a public entity, or be subjected to discrimination by any such entity."

As required by Title II of the ADA, 28 CFR. Part 35 Sec. 35.105 and Sec. 35.150, in 2010-2012, MnDOT conducted a self-evaluation of its facilities and developed a Transition Plan detailing how the organization will ensure that all of its facilities, services, programs, and activities are accessible to all individuals.

The ADA Curb and Sidewalk database is one part of MnDOT's self-evaluation. The evaluation is a geospatial collection of pedestrian facilities within its public rights of way. The assets that have been inventoried include curb ramps, accessible pedestrian signals, sidewalks, and trails. The data is collected using handheld GPS units to spatially map the assets and to collect measurements and conditions. Assets are currently collected using an application developed for ArcGIS Collector and the data is stored in the cloud. TAMS has been configured to accommodate a form of the ADA curb and sidewalk data. Each year, the previous year's construction projects are re-evaluated to ensure compliance with current MnDOT standards.

MAINTENANCE AND CAPITAL INTEGRATION

MnDOT has been working toward more fully integrating decision-making between its capital and maintenance/operations functions. Beginning in 2013, as its pilot TAMP was under development, the department initiated a project to accurately capture expense and outcomes of the work of its internal staff. The goal was to understand costs at a level that cost models could be built with, which would be sensitive to infrastructure condition and thus be responsive to the results of capital investment strategies proposed under MnSHIP. During the preparation of the 2017 MnSHIP, MnDOT was able to forecast impacts to its pavement and bridge maintenance workloads based on outcomes of the various investment level scenarios. While the data was used for informational purposes during that initial effort, MnDOT's goal is to continue to refine this approach to eventually allow "budgeting by products and services" in a manner that directly relates work needs to asset conditions.

MnDOT also seeks to minimize the life cycle costs of owning its assets. Figures in Chapter 6 – Life Cycle Planning now include specifically modeled MnDOT maintenance costs for activities included in the life cycle cost analysis. This work has begun to inform the department about activities that can be done with internal staff, which yield a high return on investment in terms of asset life (e.g., MnDOT's pavement crack sealing efforts may yield a return on investment of over 10 to 1). This knowledge has encouraged field staff to prioritize this type of effort. Currently, MnDOT is able to model costs for pavement, bridge, overhead sign structures, and culverts with relative confidence.

The effort invested in creating this TAMP was valuable in joining perspectives of both capital investment and field maintenance management staff. As MnDOT works to create a formal asset management policy, a culture of collaboration and integration is supported by efforts such as this.

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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.

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, such as tracking asset conditions for culverts and stormwater tunnels, have been monitored and used internally for managing asset-specific programs and for establishing funding needs for each asset in order to meet the target. Figures 3-1 and 3-2 list MnDOT's asset performance measures. Short descriptions of each measure's rating scale and criteria are also included, along with MnDOT targets (where applicable). Targets, both state-and federally required, are the subject of the final two sections of this chapter. Visual representations of the performance rating scales can be found in Chapter 4: Asset Inventory and Condition.

PAVEMENT

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 on all NHS and state-owned roads. This information is used to determine a Surface 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. MnDOT reports pavement condition on the National Highway System, regardless of ownership, to the Federal Highway Administration annually.

BRIDGE

Most bridges are inspected on two-year intervals and the results are reported to the FHWA annually. Bridge inspections assess the condition of the decks, superstructures, substructures, and large culverts using a standardized national inspection procedure. Inspection results are used to determine which bridges are in good, satisfactory, fair or poor structural condition. Bridges in good or satisfactory condition generally require only maintenance or preservation activities, while bridges in fair or poor condition may require major capital investments. Bridge inspection, inventory, and condition data are managed and reported by MnDOT for all bridges in the state, regardless of ownership. Communication with all owners occurs on a regular basis, including audits of inspection data.

Figure 3-1: MnDOT Pavement and Bridge Performance Measures and Targets

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	STATE TARGET
Pavements	Share of system lane miles with good or 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 enough that most people would find it uncomfortable and may decrease their speed.	Good ≥ 70% (Interstate) ≥ 65% (Other NHS) ≥ 60% (Non-NHS) Poor ≤ 2% (Interstate) ≤ 4% (Other NHS) ≤ 10% (Non-NHS)
Bridges	Share of system bridges in good or 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.	Good ≥ 55% (NHS) ≥ 50% (Non-NHS) Poor ≤ 2% (NHS) ≤ 8% (Non-NHS)

Note: 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 *2017 Pavement Condition Annual Report*. Additional bridge measures can be found in MnDOT's *MinnesotaGO Performance Dashboard*.

ALL OTHER ASSETS

MnDOT performance measures and targets for other state assets are described in Figure 3-2. Inspections of these assets are typically performed less frequently and some use age-based assumptions. However, they all use standard rating scales and management systems within each asset class. The advantage of this standardization is consistency across asset classes which can be used to prioritize repair and/or maintenance.

For example, highway culverts are managed in the Transportation Asset Management System. The system tracks inventory, 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. A condition rating of 0 also exists for culverts indicating that the culvert was not able to be inspected due to significant submergence or extensive sedimentation. 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.

Figure 3-2: Performance Measures and Targets for All Other Assets

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	STATE TARGET
Highway Culverts	Share of culverts in 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.	≤ 10%
Deep Stormwater Tunnels	Tunnels in 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 (rating 4) have significant cracks and voids behind the unreinforced tunnel liner. Tunnels with condition rating 5 have defects that require timely corrective action.	≤ 10%
Overhead Sign Structures	Share of overhead sign structures in poor condition	Overhead sign structure condition is assigned during inspections. Poor condition is dependent upon loose nuts, improper thread engagement, tilt, the presence of grout, and several other defects.	≤ 6%
High-Mast Light Towers	Share of high-mast light towers in poor condition	High-mast light tower condition is assigned by the Bridge Office on a five-year cycle. The assessment inspects the structure, LED luminaires, and tightens the nuts--among other general maintenance.	≤ 6%

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	STATE TARGET
Noise Walls	Share of noise walls in poor condition	Noise wall condition assignment frequency varies by district. In assessing the condition of a noise wall, a two-prong approach is taken. The first approach is based on the inspectors' subjective overall view of the wall. The second approach is a numerical analysis based upon the number of, and severity of, defects discovered during the inspection. The combination of these two approaches give an overall Health Index score for each wall.	< 8%
Signals and Lighting	Share of signals and lighting structures beyond useful life (30 years or older)	There is no consistent statewide frequency for collecting data on signal structures and lighting. Greater Minnesota districts complete operational inspections every few years. Metro District performs annual operational inspections.	< 2%
Pedestrian Infrastructure	Share of curb ramps and sidewalk (miles) that are non-ADA compliant	Curb ramps and sidewalk compliance ratings are based on Federal ADA compliance standards. Assets that have been part of a new project are evaluated the following construction season, otherwise the condition is evaluated every 10 years. The condition rating looks for deflections and surface irregularities.	Varies
Buildings	Share of buildings in poor condition	Building condition is assigned by the Building Services/Office of Maintenance once every three years. Facilities Condition Assessment scores buildings from excellent to poor.	Varies
Intelligent Transportation Systems	Share of sub-asset approaching or beyond useful life	ITS assets are monitored continuously as they provide data on the operation of the trunk highway system. Complete inspections for each asset range from yearly to every five years.	Varies

Note: state targets vary for pedestrian infrastructure, buildings, and ITS, as they are broken out by sub-type. See Chapter 4 for complete list.

FEDERAL PERFORMANCE MEASURES AND TARGETS

As part of MAP-21, the FHWA requires state DOTs to report performance outcomes and set targets for pavement and bridge condition, as well as other non-asset performance areas. These federal measures may not match MnDOT's measures. Moreover, the federal targets are set for two-and four-year outcomes whereas MnDOT targets apply regardless of the year. The federal measures are displayed in Figure 3-3.

MnDOT has used a combination of internal work-group target identification and Metropolitan Planning Organizations coordination and feedback to select targets for bridge and pavement MAP-21 measures on the NHS. Initially, internal MnDOT workgroups met to discuss measures, gather data and set initial proposed targets. This process involved reviewing data from bridge and pavement asset management systems on current and projected bridge and pavement conditions. These workgroups also used existing long-term performance goals and planned projects to identify short-term proposed targets. Representatives from these workgroups met with MPOs on two occasions to: 1) provide information on the measure and MPO data, and 2) propose statewide targets for these measures. Following these meetings, MnDOT internal workgroups incorporated any MPO feedback on statewide targets before bringing these targets to MnDOT's senior leadership and external partners, as needed, for approval. The current approved MnDOT federal targets are shown in Figure 3-3. MnDOT anticipates these targets will be met given programmed investments in the STIP.

The targets in Figure 3-1 and Figure 3-2 above are designed to achieve acceptable or desired outcomes for these particular assets. These targets are typically based on lowest life cycle costs, customer expectations or a policy priority. 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 also serve as the basis for MnDOT's unconstrained investment need. Of the $39 billion 20-year need reported in MnSHIP, $16 billion (41 percent) reflects the cost to meet MnDOT's pavement and bridge targets.

Figure 3-3: Federal Performance Measures and Targets

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	FEDERAL 2-YEAR TARGET (2020)	FEDERAL 4-YEAR TARGET (2022)
Pavements	Share of Interstate pavements in good or poor condition	Measure includes roughness, rutting/faulting, and cracking calculations. A segment of pavement is poor if two out of three measures are poor. A segment is good if all three measures are good	N/A	55% Good 2% Poor
Pavements	Share of non-Interstate NHS pavements in good or poor condition	See Above	50% Good 4% Poor	50% Good 4% Poor
Bridges	Share of NHS bridge deck area in good or poor condition	Measure is based on NBI condition ratings	50% Good 4% Poor	50% Good 4% Poor

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.

- State Targets refer to MnDOT targets that are used for performance-based planning and asset management planning. MnDOT targets represent acceptable or 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 trade-off decisions.

  Targets can be stated as fixed benchmarks against which MnDOT evaluates past, present, and future performance. 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.

- Federal Targets refer to the required two-and four-year targets that must be submitted to the Federal Highway Administration to report on federal performance measures. The targets must be set by the state DOT in coordination with stakeholders. These targets are not desired outcomes, but are roughly the expected outcome for the asset condition in two-and four-years based on projects in the existing program. In addition to asset condition, the federal targets cover fatalities, serious injuries, system reliability, congestion reduction, freight movement and economic vitality, environmental sustainability, and reduced project delivery delays. This document will reference federal targets and measures only briefly and focus more on MnDOT measures and targets.

- Expected outcomes reflect predictive modeling of future performance. MnDOT manages to the expected outcomes in MnSHIP for asset conditions. MnDOT projects expected 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 an expected outcome in the plan and current projections can trigger a course correction in the form of new spending priorities or a revised strategy.

Figure 3-4 summarizes the key characteristics of state targets, federal targets and expected outcomes, as explained above. Chapter 7 provides an expanded description of targets and expected outcomes for each of the asset categories covered in this TAMP.

Figure 3-4: Types of Performance Outcomes - Key Characteristics

TERM	MEANING	USE	HOW IS IT ESTABLISHED?	HOW OFTEN IS IT SET?
State 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
Federal Target	Short-term expected outcome based on programmed projects	• Federal reporting • Monitor plan implementation	Approved by senior leadership; guided by agency policies and stakeholder/partner input	Every two years
Expected Outcome	Forecasted outcome based on predictive modeling	• Develop / manage programs • Monitor plan implementation • Promote accountability / initiate corrective action	Generated by expert offices based on performance information and planned improvements	Annually

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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 approximately 4,800 bridges and 14,000 roadway miles of Interstates, US Highways and Minnesota Highways. The importance of the state highway system is demonstrated by its use. Although it comprises just 8 percent of Minnesota's total roadway system mileage, it carries almost 60 percent of the vehicle miles traveled statewide, including the majority of freight being moved by road within the state.

In addition to the assets in the TAMP, 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 assets, and traffic infrastructure within the right of way. For the majority of the multimodal assets, MnDOT manages grant programs or conveys or transfers ownership of property. It is imperative that MnDOT continues to identify ways to improve its transportation asset management practices given the significant investment in these assets. The state's transportation system requires a strategic and systematic approach to asset management.

Figure 4-1: Examples of Other Assets Managed by MnDOT

OTHER ASSET TYPES
Stormwater Collection and Treatment Systems
Sensor Systems
Sign Panels
Pavement Marking Striping
Curb and Gutter
Guardrails
Fence, Barriers, Impact Attenuators
Slopes, Embankments, Retaining Walls
Rumble Strips
Cable Median Barriers
Handholes
Pedestrian Bridges
Bicycle Facilities
Greater Minnesota Transit Vehicles
Pipes
Airports
Fleet
Right of Way

Asset Valuation

Asset valuation is assigning a monetary value to an asset based on its characteristics such as condition, age, or cost to replace. Measuring asset value gives an asset owner a benchmark to ensure they are investing sustainably. This approach does not replace other methods of measuring asset performance and system stewardship but it provides another lens to guide asset management.

The primary method of asset valuation in the TAMP is replacement value which is the cost to completely replace an asset. Collectively, the replacement value of all assets in this TAMP is roughly $48.7 billion as shown in Figure 4-2.

For pavements, bridges, culverts, and buildings, MnDOT also calculated a current asset value that reduces the replacement value based on the asset's condition or age. These assets are the highest value assets included in the TAMP and have system wide age or condition data that can be used to calculate a current value. The respective asset valuation methodologies are described on the next page. For most of these assets, current asset value takes the replacement value and depreciates, or reduces, it based on the asset's condition. Assets in better condition have a higher current asset value.

Figure 4-2: Inventory and Asset Valuation Summary as of 2017

STATE HIGHWAY SYSTEM ASSETS	UNIT/ COUNT	REPLACEMENT VALUE	CURRENT ASSET VALUE
Pavements (Roadway Miles)	14,331	$29.4 billion	$22.3 billion
Bridges	4,801	$14.6 billion	$8.5 billion
Highway Culverts	40,687	$1.6 billion	$1.2 billion
Deep Stormwater Tunnels	8	$372 million	Not calculated
Overhead Sign Structures	1,858	$175 million	Not calculated
High-Mast Light Towers	478	$19 million	Not calculated
Noise Walls	434	$374 million	Not calculated
Signals and Lighting (Signal systems and pole mounted lighting)	28,442	$541 million	Not calculated
Pedestrian Infrastructure (Curb ramps, sidewalk and pedestrian bridges)	Various Units	$279 million	Not calculated
Buildings	876	$1.2 billion	$945 million
Intelligent Transportation Systems	14,310	$151 million	Not calculated
Total	**N/A**	**$48.7 billion**	**N/A**

PAVEMENT

The replacement value for pavement is calculated as $1 million per lane-mile which represents the cost of total reconstruction. The current asset value is based on condition as measured by the Pavement Quality Index. PQI includes both surface roughness and cracking, and is measured on a scale of 0 to 5. The replacement value of a road segment is depreciated by its PQI rating to calculate the current asset value.

BRIDGE

The replacement value for bridge is calculated based on the square footage and characteristics of a bridge. Larger bridges have more complex designs that raise per square foot costs to replace. Current asset value is calculated based on the National Bridge Inventory inspection rating for each bridge component (deck, superstructure, substructure) as well as age. The NBI is on a scale of 1 to 9. Each bridge component deteriorates at a different rate and is valued differently. Bridges constructed before 1970 require upgrades to meet current design criteria so they have lower asset value.

CULVERTS

The replacement value for culverts is calculated as $40,000 per culvert (<10 feet). Current asset value is based on the culvert's current condition. Culverts are rated on a scale of 1 (new) to 4 (very poor). The current asset value for a new culvert is 100 percent of the replacement value, or $40,000. The current asset value for a very poor culvert is $0 because it should be replaced.

BUILDINGS

The replacement value for buildings is calculated based on RS Means data. RS Means is an industry standard database of construction costs based on systems and locations. With that data, the size of building, type of building, and the systems in the building, MnDOT is able to calculate the replacement value. Current asset value for a building is calculated using the insured value of the building.

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 4-3 illustrates the age profile of state highway pavements. It shows that approximately 60 percent of the network is more than 50 years old (calculated as the length of time from initial construction or reconstruction). The major spike of activity in the late 1950s through the 1960s 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. Completion of urban segments of the interstate system continued through the mid-1980s. Figure 4-4 shows a similar age profile and spikes for state highway bridges, with approximately 40 percent of MnDOT's bridges built before the mid 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.

The cost of maintaining pavements and bridges in serviceable condition increases as they approach the end of their life cycle. 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.

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

Figure 4-3: Age Profile of State Highway Pavements

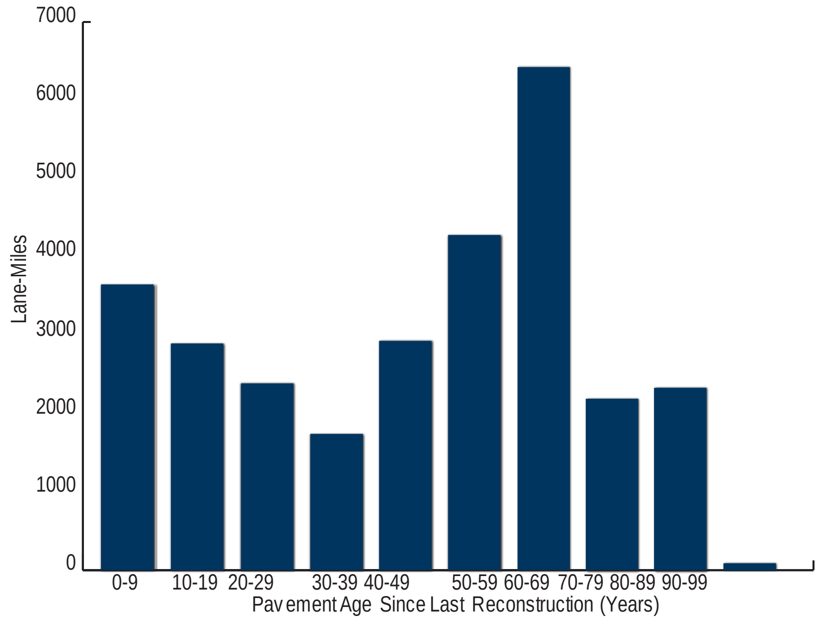
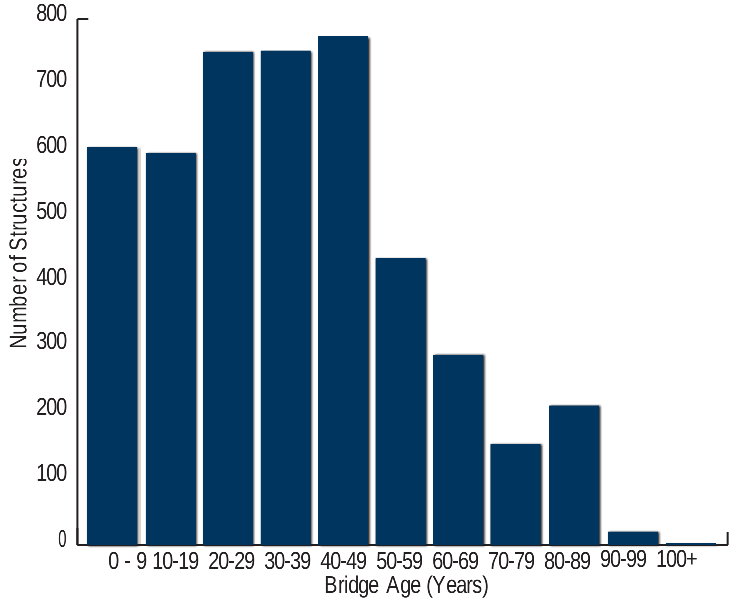


Figure 4-4: Age Profile of State Highway Bridges



damage and highlighted the need to better understand flooding impacts on asset condition. MnDOT participated in and completed 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 into asset management planning. Some of the main factors influencing the condition of the assets included in the TAMP are highlighted in Figure 4-5.

Figure 4-5: Significant Factors Influencing Asset Conditions

PAVEMENTS	BRIDGES	OTHER ASSETS
• Pavement type	• Bridge type	• Material type
• Traffic volumes	• Use of deicing chemicals	• Support of underlying foundation
• Traffic weight	• Presence of water	• Shape and geometry of culvert
• Environmental factors	• Traffic volumes	• Culvert thickness and condition
• Material properties	• Traffic weight	• Installation quality
• Type of underlying material	• Environmental factors	• Pressurization and maintenance frequency
• Maintenance frequency	• Material properties	• Fabrication quality
• Construction quality	• Maintenance frequency	• Traffic hits
	• Construction quality	• Strong winds
	• Traffic hits	• Fatigue
		• Environmental factors

A key to managing assets effectively is the ability to forecast changes in condition over time and how the use of the assets might change for each type of asset, such as higher spring load limits on pavement. MnDOT has developed sophisticated deterioration models for bridges and pavements. These models are used in the bridge and pavement management systems to predict future conditions assuming various treatment scenarios. For other asset types, deterioration models are not well established, and age-based assumptions are made.

Asset Inventory and Condition Summary

The fundamental philosophy and principles of asset management apply to all infrastructure assets maintained by MnDOT. The TAMP addresses the federally required pavement and bridge assets. The TAMP also includes "Other Assets" which are highway culverts, deep stormwater tunnels, overhead sign structures, high-mast light tower structures, noise walls, signals, lighting, ITS, pedestrian infrastructure, and buildings. Federal legislation only requires plans to include information on pavement and bridges on the National Highway System. MnDOT sees the value in expanding the TAMP federal requirements to include more assets on the entire state highway system.

A roadway mile is equal to one mile of undivided highway (all lanes and directions) or one mile of divided highway (all lanes, one direction).

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.

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 and overhead sign structures. As a result, data on maintenance history, asset condition, and deterioration rates were less than optimal for these assets. The TAMP gives MnDOT the 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.

Starting on page 51, each asset has a summary including much of the available information on the inventory, 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 around each of the asset categories considered in this TAMP. It was then vetted by the larger TAMP Project Steering Committee and Advisory Group before inclusion in this plan.

PAVEMENTS

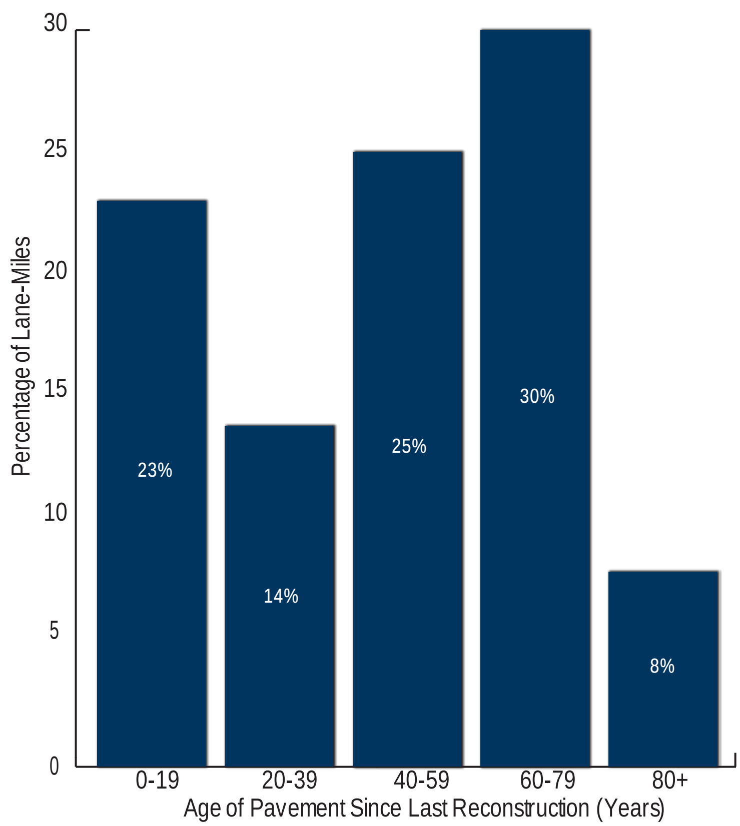
Pavements are a critical part of MnDOT's transportation network, providing mobility and access to a wide range of users. MnDOT's system consists of two types of pavements: flexible and rigid. Flexible pavements are often referred to as asphalt, bituminous or black top, while rigid is commonly referred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

Figure 4-6: Pavement Inventory and Replacement Value

SYSTEM / FUNCTIONAL CLASSIFICATION	FLEXIBLE ROADWAY MILES	RIGID ROADWAY MILES	TOTAL ROADWAY MILES	TOTAL LANE-MILES	REPLACEMENT VALUE
Interstate	925	896	1,821	4,036	$4.04 billion
Other 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

Note: Interstate and Other NHS do not include locally owned NHS roadways (see Figure 2-8). Replacement Value based on $1 million per lane-mile. Current value is based on Road Quality Index of pavements. See Figure 4-2 for current asset valuation.

Figure 4-7: Pavement Age Profile Since Last Reconstruction (by lane-mile)



Note: Age is calculated as the length of time from initial construction or reconstruction.

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 Materials and Road Research is responsible for data collection

Data Management

- Highway Pavement Management Application used to manage inventory and condition data
- Pavement condition deterioration models and project selection are conducted using the HPMA

Data Reporting

- Pavement condition report published annually by MnDOT Pavement Management Unit
- Data available on MnDOT's Pavement Management web page
- Data reported annually to FHWA's Highway Performance Monitoring System

Figure 4-8: Current Pavement Condition

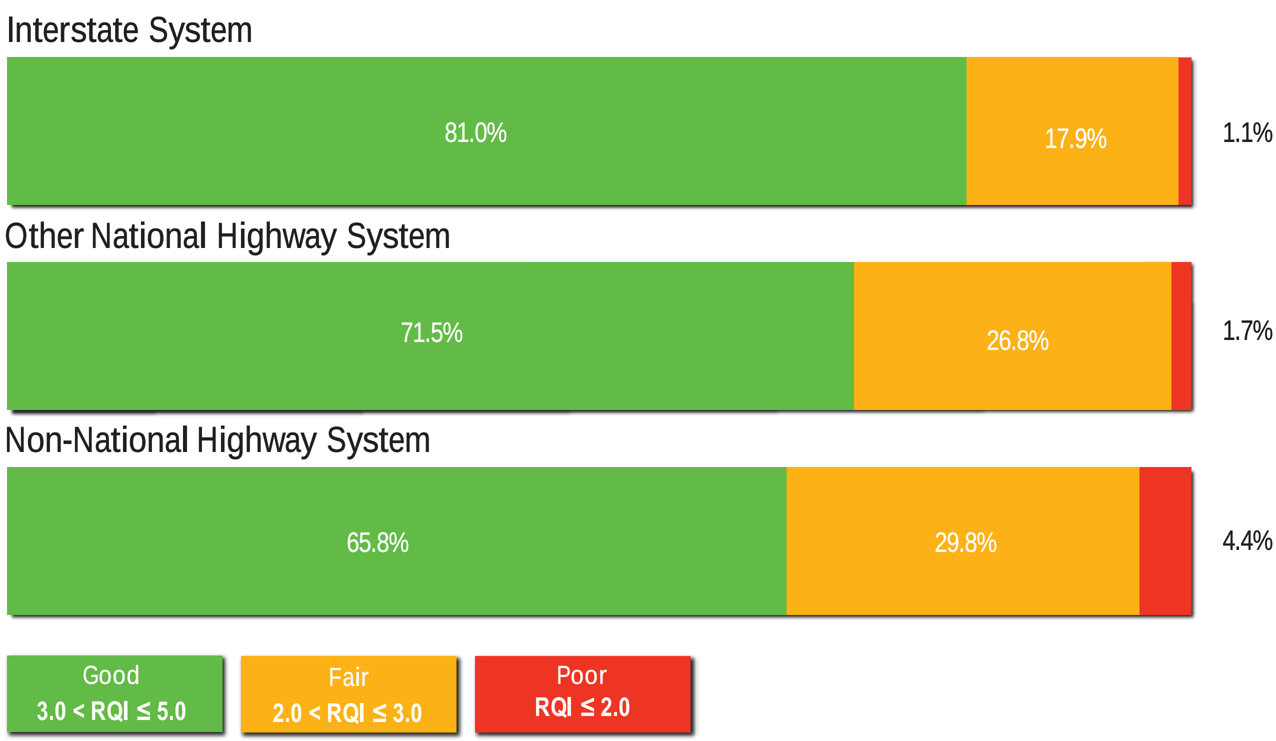


Figure 4-9: Pavement Current Condition, Targets, and Investment to Achieve Targets in 2027 Based on State Performance Measures

SYSTEM	2017 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Interstate	1.1%	≤ 2%	$747 million
Other NHS	1.7%	≤ 4%	$2.6 billion
Non-NHS	4.4%	≤ 10%	$1.7 billion

Note: Interstate and Other NHS do not include locally-owned NHS roadways (see Figure 2-8).

Federal Pavement Performance Measures and Targets

The federal pavement performance measure include roughness, rutting/ faulting, and cracking calculations. A segment of pavement is poor if two out of three measures are poor. A segment is good if all three measures are good. The figure below shows MnDOT's current pavement condition and targets according to the federal performance measure. Since MnDOT plans to meet the federal targets given currently programmed projects, the investment required to achieve targets as shown in Figure 4-10 is the programmed pavement investment between 2018 and 2021. MnDOT is in the process of updating the pavement model to include the federal pavement performance measures and be able to project the amount of investment required to achieve federal targets.

Figure 4-10: Pavement Current Condition, Targets, and Investment to Achieve Targets Based on Federal Performance Measures

SYSTEM	2017 CONDITION (% GOOD)	2017 CONDITION (% POOR)	2-YEAR TARGET (2020) (% GOOD)	2-YEAR TARGET (2020) (% POOR)	4-YEAR TARGET (2022) (% GOOD)	4-YEAR TARGET (2022) (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Interstate	60.1%	0.9%	NA	NA	55%	2%	$158 million
Other NHS	53.4%	1.3%	50%	4%	50%	4%	$444 million

Note: Figure 4-10 reports condition for all NHS regardless of ownership.

BRIDGES (INCLUDING LARGE CULVERTS)

Bridges are large, complex and expensive assets that are custom-designed and built to satisfy a wide variety of requirements. Large culverts 10 feet and greater are also included in the bridge inventory. MnDOT's bridge inventory includes all bridge structures 10 feet and greater. FHWA only includes bridge structures that are 20 feet and greater. There are currently 3,875 bridge structures over 20 feet. The remaining 920 structures are between 10 and 20 feet or are non-automobile bridges.

Figure 4-11: Bridge Inventory and Replacement Value

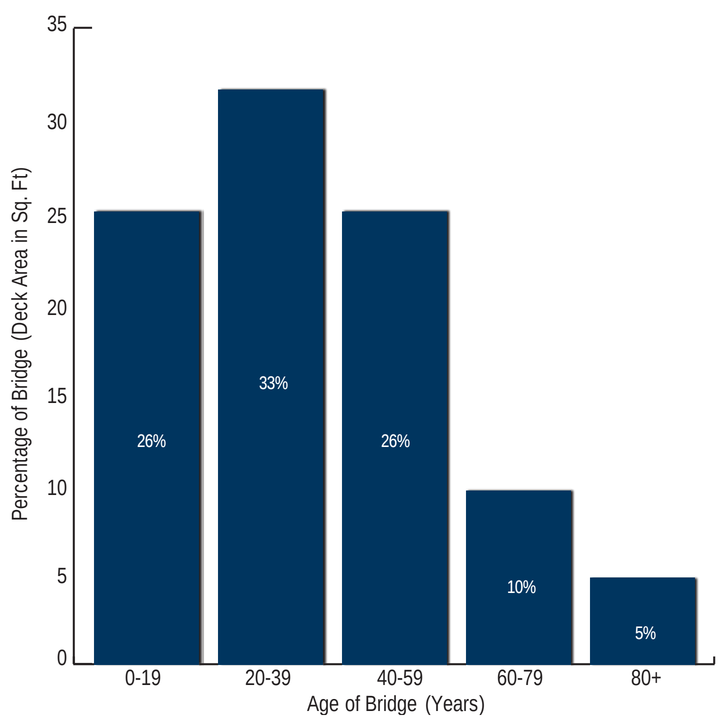
SYSTEM	BRIDGE COUNT	BRIDGE DECK AREA (SQ. FT.)	BRIDGE REPLACEMENT VALUE
NHS	1,621	31,444,986	$8.8 billion
Non-NHS	1,377	18,504,855	$5 billion
TOTAL (State Highway)	2,998	49,949,841	$13.8 billion

Note: NHS do not include locally-owned NHS bridges (see Chapter 2, Figure 2-10); replacement values range from $50/sq. ft. to $820/sq. ft. depending on bridge type, size and complexity. See Figure 4-2 for current asset valuation.

Figure 4-12: Bridge Culvert Inventory and Replacement Value

SYSTEM	BRIDGE CULVERTS COUNT	BRIDGE CULVERTS REPLACEMENT VALUE
NHS	745	$470 million
Non-NHS	1,058	$329 million
TOTAL (State Highway)	1,803	$799 million

Figure 4-13: Bridge Age Profile (by deck area in sq. ft.)



Note: Figure 4-13 does not include large bridge culvert deck area.

Data Collection, Management, and Reporting Practices

Data Collection

- Data collection based on National Bridge Inspection Standards, AASHTO and MnDOT requirements
- Most bridges are inspected every other year in Minnesota (some more or less frequently based on inspection results)
- Districts perform/supervise routine inspections with some centralized management and Quality Assurance/Quality Control of data collected
- The Central Office Bridge Office performs/supervises fracture critical inspections and manages underwater inspection contracts

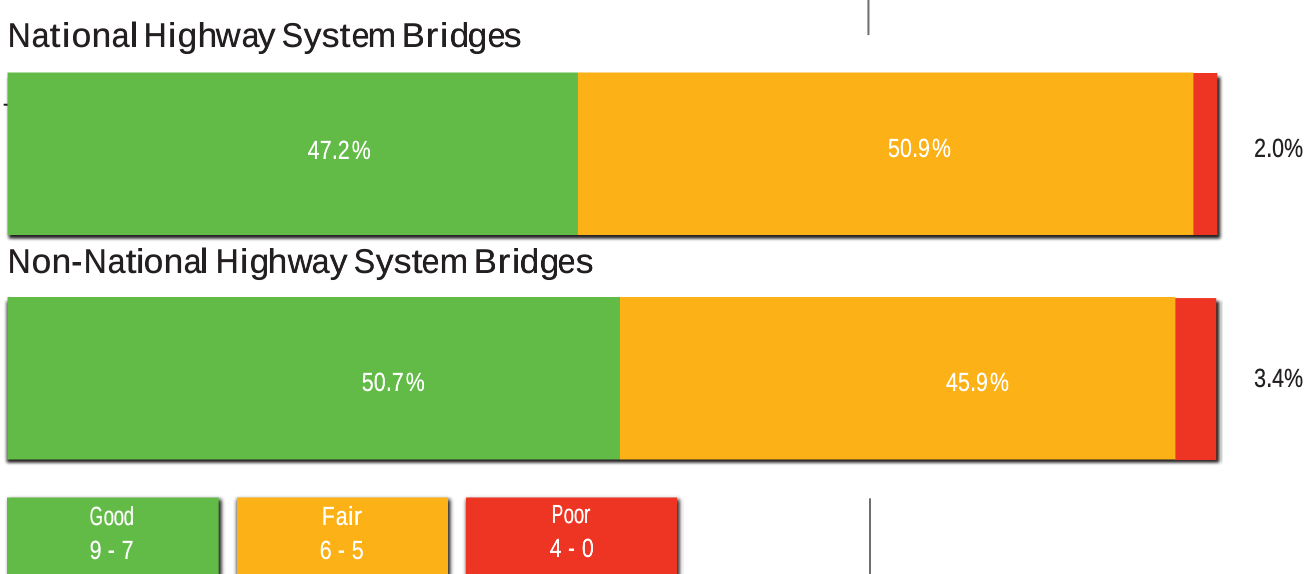
Data Management

- Structure Information Management System used to enter and manage inspection and maintenance data
- Bridge Replacement and Improvement Management tools used to analyze data

Data Reporting

- Bridge inspection and maintenance inventory reports are available through MnDOT's website and the SIMS application

Figure 4-14: Current Bridge Condition



Note: Figure 4-14 reports condition by deck area of bridge structures 10' and greater and does not include bridge culverts or locally-owned NHS bridges (see Figure 2-10)

Figure 4-15: Bridge Current Condition, Targets, and Investment to Achieve Targets in 2027 Based on State Performance Measures

SYSTEM	2017 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
NHS	2%	≤ 2%	$1.1 billion
Non-NHS	3.4%	≤ 8%	$446 million
TOTAL	2.4%	NA	$1.5 billion

Note: Figure 4-15 reports condition by deck area of bridge structures 10' and greater and does not include bridge culverts or locally-owned NHS bridges (see Figure 2-10).

Federal Bridge Performance Measures and Targets

The figure below shows MnDOT's current bridge condition and targets according to the federal performance measure. The federal performance bridge measures are based on NBI condition ratings. Since MnDOT plans to meet the federal targets given currently programmed projects, the investment required to achieve targets as shown in Figure 4-16 is the programmed bridge investment between 2018 and 2021.

Figure 4-16: Bridge Current Condition, Targets, and Investment to Achieve Targets in 2027 Based on Federal Performance Measures

SYSTEM	2017 CONDITION (% GOOD)	2017 CONDITION (% POOR)	2-YEAR TARGETS (2020) (% GOOD)	2-YEAR TARGETS (2020) (% POOR)	4-YEAR TARGETS (2022) (% GOOD)	4-YEAR TARGETS (2022) (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
NHS	48%	1.9%	50%	4%	50%	4%	$316 million

Note: Figure 4-16 reports condition by deck area of all NHS bridge structures 20' and greater regardless of ownership.

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HYDRAULIC INFRASTRUCTURE (HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS)

Hydraulic infrastructure, including centerline highway culverts (diameter less than 10 feet) and deep stormwater tunnels, plays a part in helping MnDOT effectively manage water flows throughout the state. Highway culverts convey surface water runoff from one side of the roadway embankment to the other side. They are located under MnDOT highway travel lanes, including the mainline, ramps and loops. Deep stormwater tunnels are located in the Twin Cities metropolitan area only, collect stormwater runoff (e.g., runoff from major highways and surrounding area), and are approximately 50-100 feet below the surface. All state highway system centerline culverts and deep stormwater tunnels are considered in all of the analyses (life cycle cost planning, risk management, financial plans, and investment strategies) performed as a part of this TAMP.

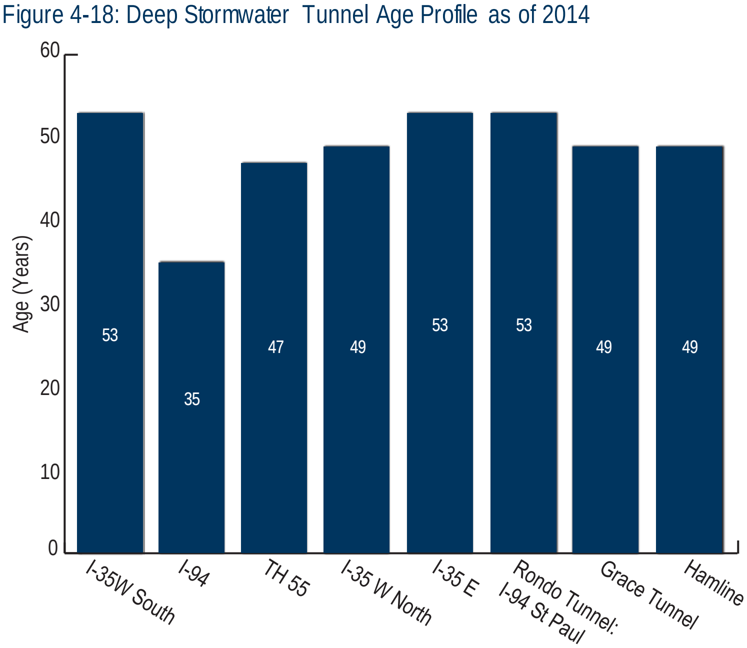
Hydraulic infrastructure including median and driveway/entrance culverts, interconnected storm sewer system piping and their associated catch basins, manholes and drop inlets, stormwater treatment systems such as ponds, infiltration/filtration basins, and structural pollution control devices are a part of the Transportation Asset Management System, but not yet included in the TAMP. As more data is collected statewide on these other hydraulic infrastructure, it is possible these could be included in future plan updates.

Figure 4-17: Hydraulic Infrastructure Inventory and Replacement Value

ASSET TYPE	COUNT / UNIT	REPLACEMENT VALUE
Highway Culverts	40,687 (number)	$1.6 billion
Deep Stormwater Tunnels	73,392 linear feet (8 tunnels)	Approximately $372 million

Note: Replacement value for centerline highway culverts based on $444 per foot, assuming average culvert length of 90 feet; replacement value for tunnels based on approximate estimate provided by hydraulic infrastructure work group. See Figure 4-2 for current asset valuation.

Figure 4-18: Deep Stormwater Tunnel Age Profile as of 2014



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 and/or Hydraulics / Water Resources Engineering, Tunnels managed by Metro District WRE
- Deep stormwater tunnel conditions are documented using the Pipeline Assessment and Certification Program developed by National Association of Sewer Service Companies
- Using standard specification for As-Builts to track new construction projects

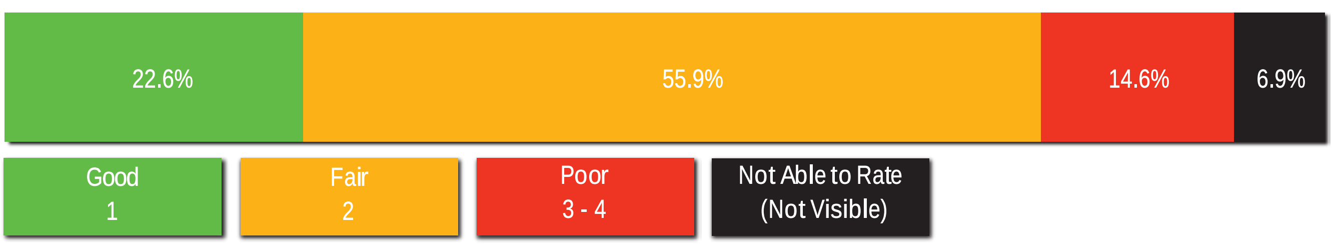
Data Management

- TAMS HydInfra information application used to manage inventory, inspection, and maintenance activities

Data Reporting

- Condition ratings extracted from TAMS HydInfra system for internal reporting purposes

Figure 4-19: Highway Culverts Condition



Note: Highway culvert age is not recorded. Only culvert's condition rating is available.

Figure 4-20: Deep Stormwater Tunnel Condition (by linear feet)

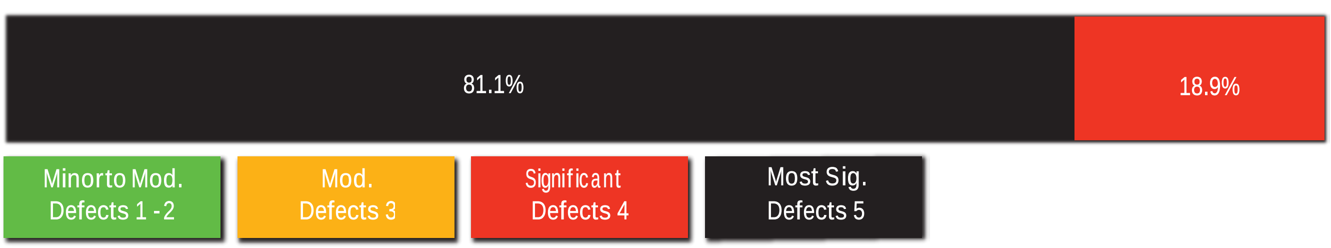


Figure 4-21: Highway Culverts and Deep Stormwater Tunnels Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Highway Culverts	15%	≤ 10%	$290 million
Deep Stormwater Tunnels	19%	≤ 10%	$4.5 million

Note: Deep stormwater tunnels are considered "Poor" if they are rated with significant or most significant defects.

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OVERHEAD SIGN STRUCTURES

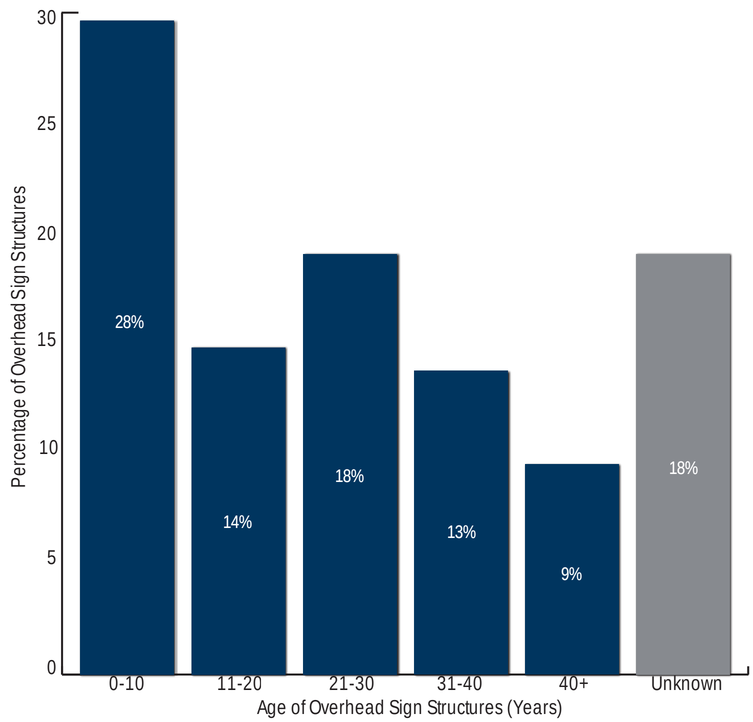
Overhead sign structures include various types of span and cantilever stand alone structures, designed to support signs requiring vertical clearance for vehicles to pass underneath. This also includes sign structures outside of MnDOT right of way that carry sign panels directing motorists to MnDOT roadways. Bridge-mounted sign structures are not considered in this asset category. The analysis performed in this TAMP accounts only for structural condition; other functional and operational requirements (e.g., sign panel condition and retroreflectivity) are not considered.

Figure 4-22: Overhead Sign Structure Inventory and Replacement Value

SYSTEM / FUNCTIONAL CLASSIFICATION	COUNT	REPLACEMENT VALUE
Overhead Sign Structures	1,858	$175 million

Note: Replacement Value is based on $125,000 per sign bridge, $150,000 per sign bridge cantilever and $75,000 for cantilever.

Figure 4-23: Overhead Sign Structures Age Profile



Data Collection, Management, and Reporting Practices

Data Collection

- Condition inspections performed in-house or via contract
- Using standard specification for As-Builts to track new construction projects
- Data collection is typically on a five-year cycle; the collection of inventory data is happening weekly / daily
- Data collection managed by the Maintenance / Traffic Division

Data Management

- Overhead sign structure data currently stored in a spreadsheet or on paper, but will be included in TAMS (Summer / Fall 2019)

Data Reporting

- Condition ratings extracted from rating spreadsheet for internal reporting purposes - statewide condition data is not available so the conditions in Metro were extrapolated statewide

Figure 4-24: Overhead Sign Structure Condition

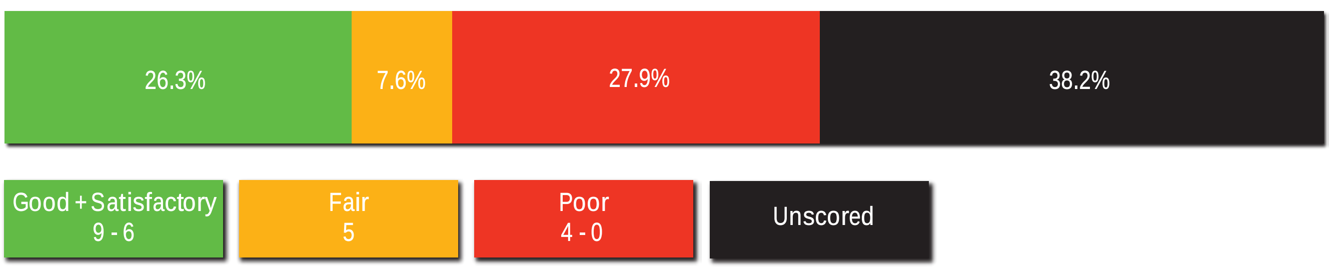


Figure 4-25: Overhead Sign Structures Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	TARGET (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Overhead Sign Structures	28%	≤ 6%	$41 million

HIGH-MAST LIGHT TOWERS

High-mast light tower structures are tall poles, 100-140 feet in height, which support three to six large lamps. The analysis performed in this TAMP accounts only for structural condition; other functional and operational requirements (e.g., luminaire replacement) are not considered.

Figure 4-26: High-Mast Light Tower Structures Inventory and Replacement Value

SYSTEM / FUNCTIONAL CLASSIFICATION	COUNT	REPLACEMENT VALUE
High-Mast Light Tower Structures	478	$19 million

Note: Replacement Value is based on $40,000 per high-mast light tower structure

Data Collection, Management, and Reporting Practices

Data Collection

- Condition inspections performed in-house or via contract
- Using standard specification for As-Builts to track new construction projects
- Data collection typically on a five-year cycle
- Data collection managed by the Bridge Office

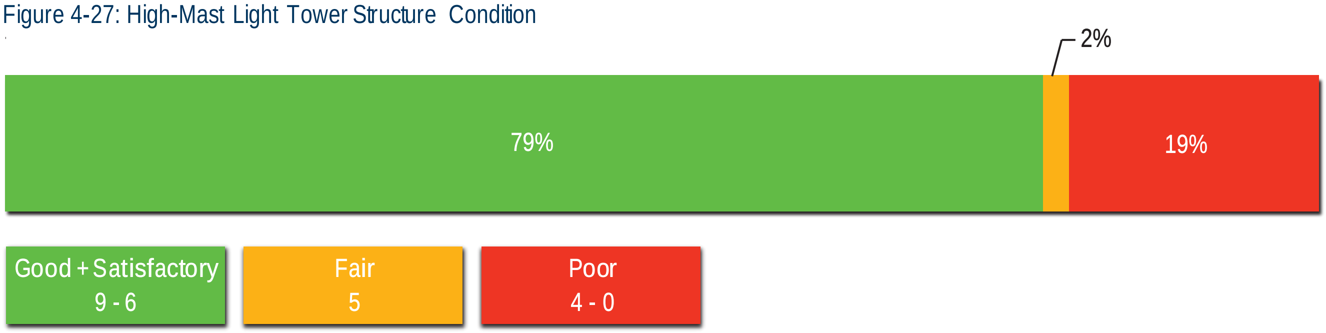
Data Management

- High-mast light tower structure data stored in TAMS and in an Access database

Data Reporting

- Condition ratings extracted from rating spreadsheet for internal reporting purposes

Figure 4-27: High-Mast Light Tower Structure Condition



Note: High-Mast Light Tower age data is not available systemwide.

Figure 4-28: High-Mast Light Tower Structures Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	TARGET (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
High-Mast Light Tower Structures	19%	≤ 6%	N/A*

*MnDOT is unable to estimate future condition due to unpredictable deterioration of these assets.

NOISE WALLS

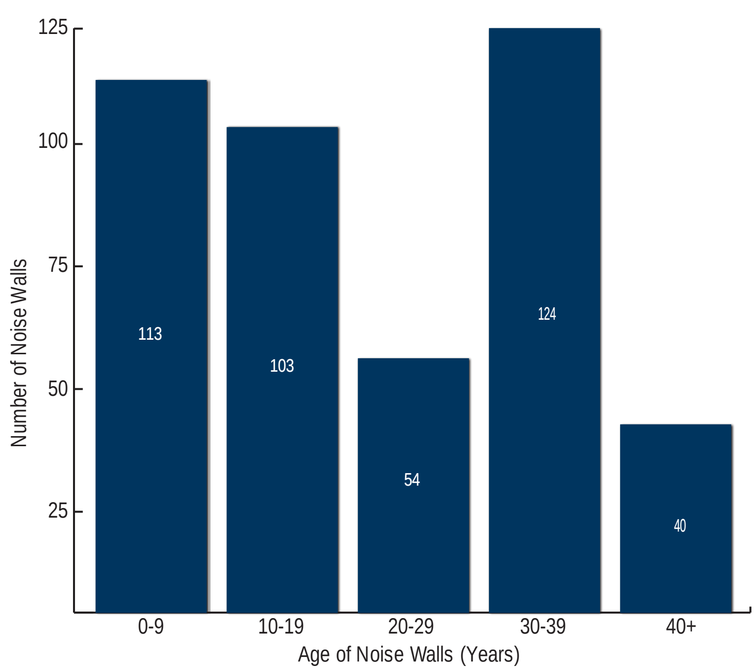
Noise walls are large structures that block the direct path of sound from highways to nearby communities. MnDOT conducts noise studies to assess existing noise levels and predict future noise levels based on transportation-related projects under development. MnDOT is required by federal law to consider noise mitigation measures, including installation of noise walls. Requirements established by federal law, Federal Highway Administration Noise Abatement Criteria, Minnesota Pollution Control Agency State Noise Standard, and MnDOT's noise requirements and noise analysis guidelines all impact the location and design of noise walls. The most recent update to the agency's noise requirements was in July 2017. MnDOT currently owns 434 noise walls, of which 95 percent are located in the Twin Cities Metro area. Targets and investment needs are set based on condition improvement, not to add new walls for noise abatement.

Figure 4-29: Noise Walls Inventory and Replacement Value

WALL TYPE	COUNT	WALL AREA (SQ. FT.)	REPLACEMENT VALUE
Wood*	364	10,080,028	$312 million
Concrete**	70	1,431,654	$62 million
TOTAL	434	11,511,682	$374 million

Note: Replacement values range from $25/sq. ft. to $43/sq. ft. depending on noise wall type
*Wood walls include wood post/wood panel, concrete post/wood panel, wood glulam, and acrylic.
**Concrete walls include concrete post/concrete panel, concrete block, concrete panel, and steel.

Figure 4-30: Noise Walls Age Profile



Data Collection, Management, and Reporting Practices

Data Collection

- Using standard specification for As-Builts to track new construction projects
- Condition collected in 2012 and 2019
- Frequency of data collection varies by district
- The current noise wall condition assessment is based on a Health Index Score. It incorporates both a subjective rating and a scoring formula by defect severity and type

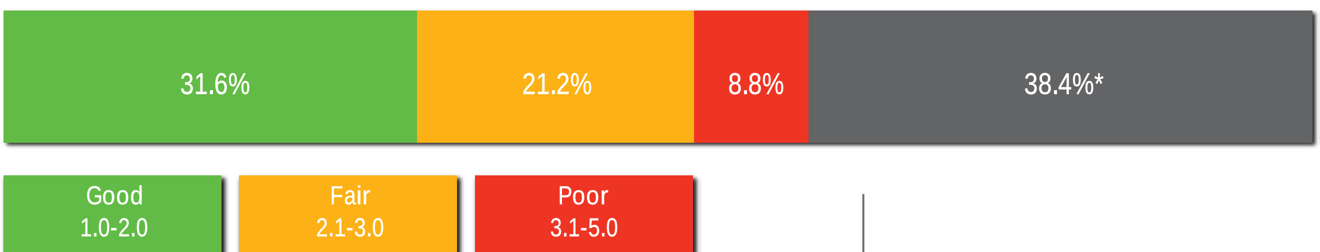
Data Management

- Inventory and condition data are stored in a spreadsheet and in the future will be contained in TAMS

Data Reporting

- Location, project identification and cost reported annually to Federal Highway Administration

Figure 4-31: Noise Wall Health Index



Note: Noise walls less than 10 years old are unscored and make up 38.4% of current walls--this segment is colored gray. Condition ratings have never been assumed for these walls.

Figure 4-32: Noise Walls Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	TARGET (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Noise Walls	11%	≤ 8%	$154 Million

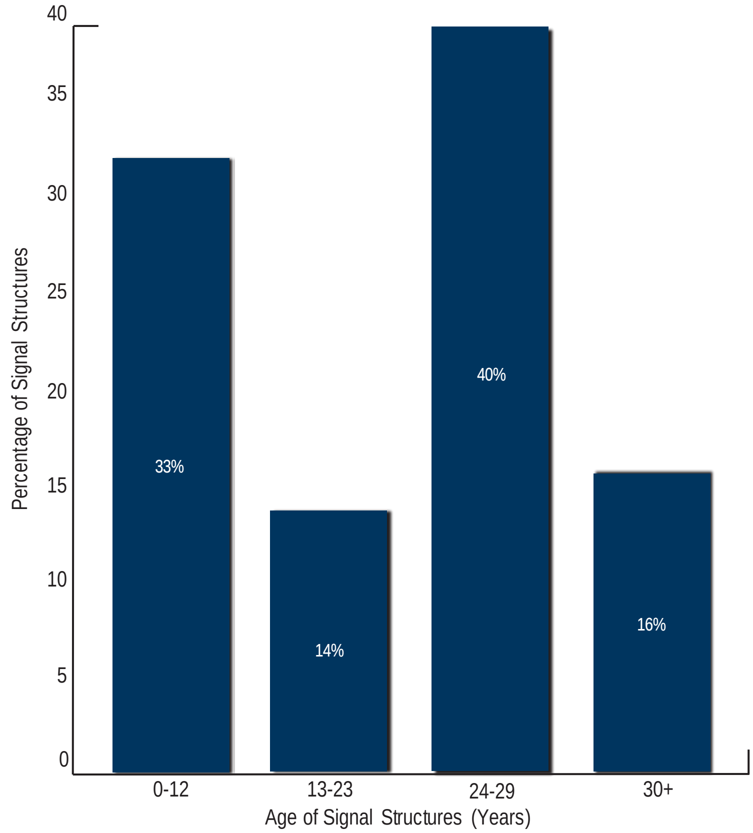
SIGNALS AND LIGHTING

Traffic signals and lighting structures are important assets on the state highway system. MnDOT currently owns approximately 1,300 traffic signals and more than 27,000 lighting structures. These assets are managed by district offices and the Office of Traffic Engineering and maintained by the MnDOT Signals and Lighting Section. Traffic signals are inspected annually for operations, every two years for electronics, every three years for electrical and an acceptance check after every new structure is added.

Figure 4-33: Signals and Lighting Inventory and Replacement Value

SYSTEM	COUNT	REPLACEMENT VALUE
Traffic Signal Systems	1,295	$324 million
Lighting Structures	27,147	$217 million
TOTAL	28,566	$541 million

Figure 4-34: Signals Age Profile



Data Collection, Management, and Reporting Practices

Data Collection

- No consistent statewide frequency for collecting data on signal structures and lighting
- Using standard specification for As-Builts to track new construction projects
- Greater Minnesota districts complete inspections every few years
- Metro District performs/supervises annual operational inspections with some centralized management and Quality Assurance/Quality Control of data collected, but no regular structural inspections are in place

Data Management

- Electrical and electronic inspection data stored in TAMS
- Repair activity and cost data stored in TAMS

Data Reporting

- No standard practice or required reports

Figure 4-35: Signals and Lighting Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% BEYOND USEFUL LIFE*)	TARGETS (% BEYOND USEFUL LIFE*)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Traffic Signal Systems	16%	≤ 2%	$235 million
Lighting	31%	≤ 2%	$144 million

*Beyond useful life is defined as 30 years or older

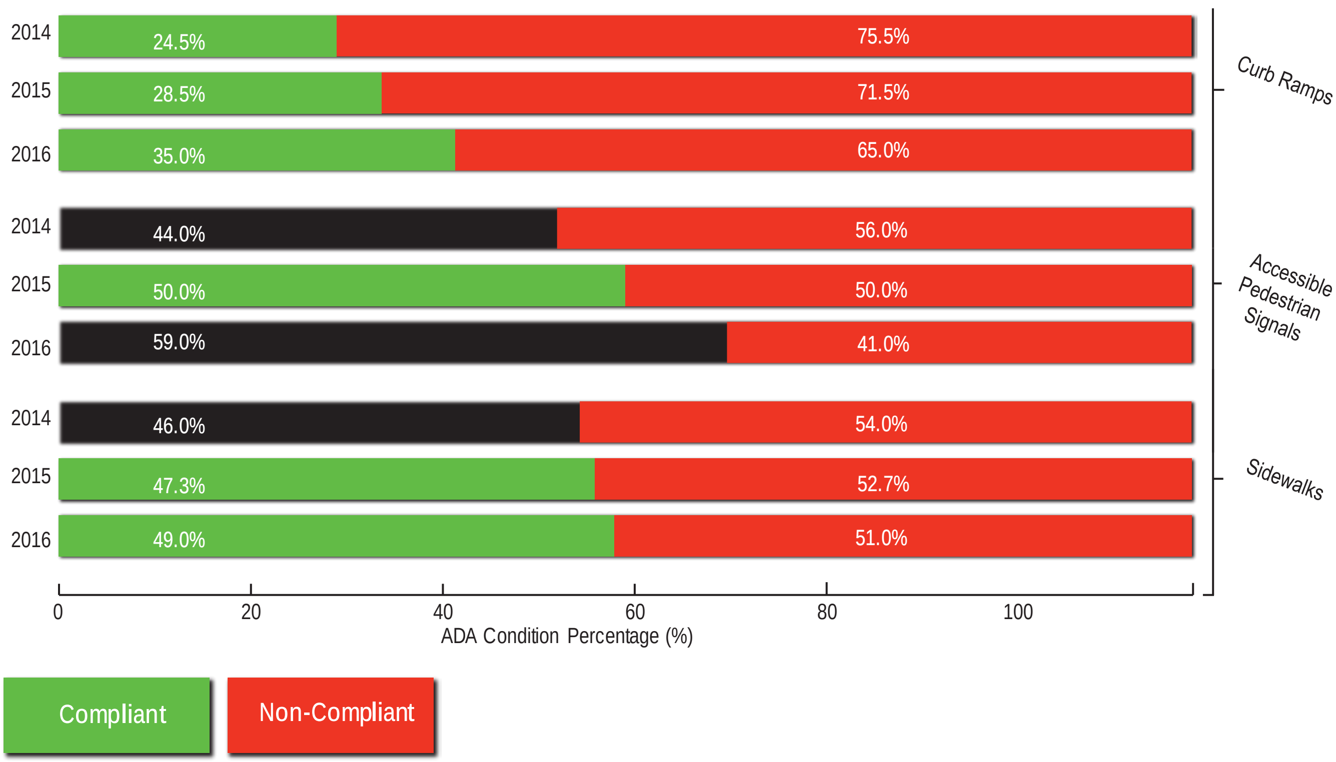
PEDESTRIAN INFRASTRUCTURE

Pedestrian assets include infrastructure that aid in making traveling along side or across roadways accessible to all pedestrians. These include curb ramps, sidewalks, and driveways with sidewalks. MnDOT currently owns over 560 miles of sidewalks and over 21,000 curb ramps. The information about the assets are collected and maintained by the Operations Division. For the TAMP effort, pedestrian infrastructure is subject to two performance measures: compliance with federal Americans with Disability Act regulations and a MnDOT compliance target. This asset management effort will be useful as MnDOT is currently preparing its first pedestrian system plan.

Figure 4-36: Pedestrian Inventory and Replacement Value

ASSET TYPE	COUNT/ AREA	COST PER UNIT	REPLACEMENT VALUE
Curb Ramps	21,175	$3,000	$64 million
Sidewalk	9,151,206 sq. ft.	$9/ sq. ft.	$82 million
TOTAL	N/A	N/A	$146 million

Figure 4-37: ADA Compliance of State Highway System



Note: Compliance percentages are found in the 2014-2016 Minnesota Quarterly Olmstead Plan

Data Collection, Management, and Reporting Practices

Data Collection

- Data was collected for the first time in 2010 - 2013 as part of the ADA Transition Plan
- Districts collected data
- Inspections and data collection will ideally be done every 10 years

Data Management

- Data managed in an internal inventory by Operations Division staff

Data Reporting

- Data reported in ADA Transition Plan
- District and central offices use data to scope pedestrian infrastructure projects in tandem with bridge and pavement projects

Note: For ramps, ADA compliance requirements include specific geometric standards and accessible pedestrian signals

Figure 4-38: Pedestrian Infrastructure Compliance, Targets, and Investment to Achieve Targets in 2027

ASSET TYPE	2017 COMPLIANCE (% NON-ADA COMPLIANT)	TARGETS (% NON-ADA COMPLIANT)	INVESTMENT REQUIRED TO ACHIEVE TARGETS OVER 10 YEARS**
Curb Ramps	61%	≤ 6%	$180 million
Sidewalk*	44%	≤ 5%	$174 million

*Compliance ratings based on ADA compliance standards. Significant effort is underway to meet substantial (3% cross-slope) compliance.

**These projected investments do not include other costs typically added to pedestrian projects (an additional 40%).

BUILDINGS

MnDOT owns, operates and maintains a wide variety of buildings to support the state's transportation infrastructure. These buildings vary widely in terms of purpose, size and location, and include rest areas, salt sheds, and MnDOT headquarter buildings. MnDOT owns approximately 875 buildings that vary in size from 100 sq. ft. to 175,000 sq. ft.

Figure 4-39: Building Inventory and Replacement Value

BUILDING TYPE	COUNT	REPLACEMENT VALUE*
Rest Areas	51 (Class 1)	$35.5 million
Weigh Stations/ Scales	7	$5.5 million
Class 2 and 3 Truck stations (small and medium)	119	$234.5 million
Class 1 Truck stations (large)	33	$598.9 million
Salt sheds	202	$86.8 million
Storage sheds (heated, partially heated, and unheated)	354	$125.4 million
Office Buildings	5 (special service sites)* 2 (Roseville Waters Edge)** 3 (state patrol offices)	$57.1 million
Miscellaneous Buildings	100 (tunnel and bridge service, brine, emergency generators, lift stations, class 2 rest areas, WIM, anti-icing, and hazmat bldgs)	$33.3 million
TOTAL	876	$1.2 billion

Note: Values represent replacement in-kind and not the cost to replace code-compliant buildings that meet operational and capacity needs. Values represent that of the building only. It does not include such items as vehicular pavements and ramps, site amenities, exterior lighting, and scale mechanisms. See Figure 4-2 for current asset valuation.

*MnDOT's Central Office is not included as it is owned by the Department of Administration.

**Metro District's offices in Roseville (Water's Edge) are technically two buildings connected by a skyway and are treated as such.

Data Collection, Management, and Reporting Practices

Data Collection

- Operations Division works with district plant management offices as well as with Specialty Offices related to rest areas and weigh scales
- Data collected every three years on buildings

Data Management

- ARCHIBUS facilities management software is used to enter, submit, and manage inspection and maintenance data

Data Reporting

- Data is reported annually to the Minnesota Department of Administration

Figure 4-40: Building Condition Rating Scale

Excellent	Good	Average	Poor
0.0-0.05	0.06-0.15	0.16-0.30	>0.31

Figure 4-41: Building Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Rest Areas and Weigh Stations/ Scales	12% (Rest Areas) 0% (Weigh Stations/Scales)	≤ 4% (Rest Areas) ≤ 15% (Weigh Stations/Scales)	$84 million
Other Buildings • Class 2 and 3 Truck stations (medium and small) • Class 1 Truck stations (large) • Salt sheds • Storage sheds (heated, partially heated, and unheated) • Storage sheds (unheated) • Office buildings • Miscellaneous buildings	1% (Class 2 and 3 truck stations) 0% (Class 1 truck stations) 10% (Salt sheds) 4% (Heated storage sheds) 8% (Unheated storage sheds) 0% (Office buildings) 15% (Miscellaneous buildings)	≤ 5% (Class 2 and 3 truck stations) ≤ 3% (Class 1 truck stations) ≤ 15% (Salt sheds) ≤ 10% (Heated and unheated storage sheds) 0% (Office buildings) N/A (Miscellaneous buildings)	$309 million
TOTAL	N/A	N/A	$393 million

Note: investment required to achieve targets considers a large amount of buildings expected to reach poor condition over the next 10 years.

INTELLIGENT TRANSPORTATION SYSTEMS

ITS assets are electronics, communication or information processing systems or services used to improve the efficiency and safety of the surface transportation system. They include dynamic message signs, traffic monitoring cameras, MnPASS readers, Road Weather Information Systems, and other information and communication systems.

Figure 4-42: ITS Inventory and Replacement Value

ITS ASSET TYPE	COUNT	REPLACEMENT VALUE
Fiber communication network	703 miles	$24.6 million
Fiber network shelters	71	$7.8 million
Traffic Management System cabinet	1,343	$13.4 million
Dynamic Message Signs	734	$54.9 million
Traffic monitoring cameras	942	$4.7 million
Traffic detector stations/site-loops and radar (5 mobile units not included in count)	7,733	$11.6 million
Communication equipment - Ethernet backbone devices - Ethernet communication equipment - Video transmission equipment - Video en/decoding devices (pairs)	1,878	$5.6 million
MnPASS readers	43	$0.4 million
Reversible road gates	29	$0.7 million
Ramp meters	486	$2.9 million
Rural Intersection Conflict Warning Systems	54	$8.1 million
Road Weather Information Systems Sites	98	$5.9 million
Automatic Traffic Recorders	71	$3.7 million
Weigh-In-Motion System Sites	24	$5.2 million
Road closure systems	101	$1.0 million
TOTAL	N/A	$150.7 million

Data Collection, Management, and Reporting Practices

Most ITS infrastructure assets are located and managed within Metro District. This includes the fiber communication network, fiber network shelters, traffic management system cabinets, dynamic message signs, traffic monitoring cameras, traffic detector stations/sites, MnPASS readers, communication equipment, reversible road gates, and ramp meters. Rural intersection conflict warning systems, road weather information systems sites, automatic traffic recorders, weigh-in-motion system sites, and road closure systems are located and managed by the various MnDOT districts and specialty offices.

Data Collection

- ITS assets are monitored continuously as they provide data on the operation of the trunk highway system
- Inspections of the condition varies by asset ranging from annually to every five years

Data Management

- All ITS assets are managed in TAMS

Data Reporting

- No official reporting of ITS data

Figure 4-43: ITS Assets Rating Scales

Rural Intersection Conflict Warning Systems	Good <5 years	Fair 5-9 years	Poor 10-14 years	Critical >14 years	
Road Weather Information System - Electrical Components	Good <4 years	Fair 4-7 years	Poor 8-10 years	Fail >10 years	
Road Weather Information System - Structure	Good <21 years	Fair 21-35 years	Poor 36-40 years	Fail >40 years	
Automatic Traffic Recorders and Weight-In-Motion Controllers	Very Good <4 years	Good 4-6 years	Fair 7-9 years	Poor 10-12 years	Very Poor >12 years
Automatic Traffic Recorders and Weight-In-Motion Sensors*	Good > 3.0 RQI	Fair 3.0-2.1 RQI	Poor ≤2.0 RQI		
Road Closure Systems	Good <3 years	Fair 3-32 years	Poor 33-39 years	Very Poor >39 years	

Note: sensors in Automatic Traffic Recorders and Weight-In-Motion sites are in the roadways pavement surface and their deterioration is tied to the pavement's ride quality index

Figure 4-44: Metro Specific ITS Assets Rating Scales

Fiber Communication Network	Good <15 years	Fair 15-19 years	Poor 20-24 years	Critical >24 years
Fiber Network Shelters	Good <10 years	Fair 10-14 years	Poor 15-19 years	Critical >19 years
Traffic Management System Cabinet	Good <8 years	Fair 8-15 years	Poor 16-20 years	Very Poor >20 years
Dynamic Message Signs	Good <9 years	Fair 9-12 years	Poor 13-14 years	Very Poor >14 years
Analog Traffic Monitoring Cameras*	Good <5 years	Fair 5-9 years	Poor 10-14 years	Very Poor >14 years
IP Traffic Monitoring Cameras	Good <5 years	Fair 5-8 years	Poor 9-11 years	Very Poor >12 years
Traffic Detector Stations/Site Loops and Radar	Functional ≤14 years	Non-Functional >14 years		
MnPASS Readers	Good <10 years	Fair 10-12 years	Poor 13-14 years	Very Poor >14 years
Communication Equipment**	Functional ≤ 10 years	Marginal >10 years	Non-Functional Hardware Failure	
Reversible Road Gates	Good <9 years	Fair 9-12 years	Poor 13-16 years	Very Poor >16 years
Ramp Meters	Good <25 years	Average 25-49 years	Poor >49 years	

* Analog Traffic Monitoring Cameras are being phased out of service and being replaced with IP Traffic Monitoring Cameras

**Generally communication equipment technology has been updating every 10 years. Equipment may still be functional after 10 y ears but may be technologically obsolete and scheduled to be replaced.

Figure 4-45: ITS Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% APPROACHING OR BEYOND USEFUL LIFE*)	TARGETS (% APPROACHING OR BEYOND USEFUL LIFE*)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Metro Specific ITS Assets	10% (Fiber communication network) 10% (Fiber network shelters) 13% (Traffic management system cabinet) 15% (Dynamic Message Signs) 10% (Traffic monitoring cameras) 4% (Traffic detector stations/site) 20% (Communication equipment) 0% (MnPASS readers) 0% (Reversible road gates) 0% (Ramp meters)	≤ 4% (Fiber communication network) ≤ 5% (Fiber network shelters) ≤ 7% (Traffic management system cabinet) ≤ 7% (Dynamic Message Signs) ≤ 5% (Traffic monitoring cameras) ≤ 2% (Traffic detector stations/site) ≤ 5% (Communication equipment) ≤ 2% (MnPASS readers) = 0% (Reversible road gates) ≤ 2% (Ramp meters)	$82.3 million
Rural Intersection Conflict Warning Systems	0%	≤ 6%	$6.1 million
Road Weather Information Systems Sites	0%	≤ 2%	$8.0 million
Automatic Traffic Recorders and Weigh-In-Motion System Sites	No inspection criteria	≤ 10%	$11.1 million
Road Closure Systems	0%	≤ 10%	$0.8 million
TOTAL	N/A	N/A	$108.2 million

*"Approaching or Beyond Useful Life" is a combination of Poor/Non-Functional and Very Poor/Fail/Critical.

Chapter 5

RISK MANAGEMENT ANALYSIS

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RISK MANAGEMENT ANALYSIS

Overview

Risk is frequently defined as the effect of uncertainty or variability 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 incorporated risk into capital and highway operations planning, as well as into business planning for the agency's functional areas. Risk assessments have been formally incorporated into the Minnesota 20-year State Highway Investment Plan. This strong history with risk prompted MnDOT to take a customized approach to the Risk Management Analysis section of the TAMP. Because risk management is already integrated into most agency planning and management practices, MnDOT acknowledged 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. However, all risks are listed in this chapter.

MnDOT's most mature application of "global" risk management occurs at the project level. The use of sophisticated tools and data (e.g., age, condition, treatments, deterioration, etc.) help evaluate and manage global risks (e.g., catastrophic failure of bridges, highway culverts, and deep stormwater tunnels due to flooding or lack of capacity at the project level).

Risk and Transportation

Like many transportation agencies, MnDOT endeavors to provide the level of service demanded by the public at minimum cost. However, unexpected events – including external hazards, economic disruption or insufficient understanding – can reduce the effectiveness of an agency in achieving its goals. 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, construction incidents)
Asset aging 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 may include:

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

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:

- Having an inventory of assets MnDOT owns and maintains
- Conducting routine inspections to understand the condition of MnDOT's assets
- Raising awareness of risks among staff and the public
- Adopting management strategies and techniques to avoid risks
- Prioritizing risk-prone assets for replacement
- Using performance measures to mitigate and manage asset risks
- Working with partners and stakeholders on ways to reduce or to jointly manage risks through maintenance agreements, jurisdictional transfer or other management strategies

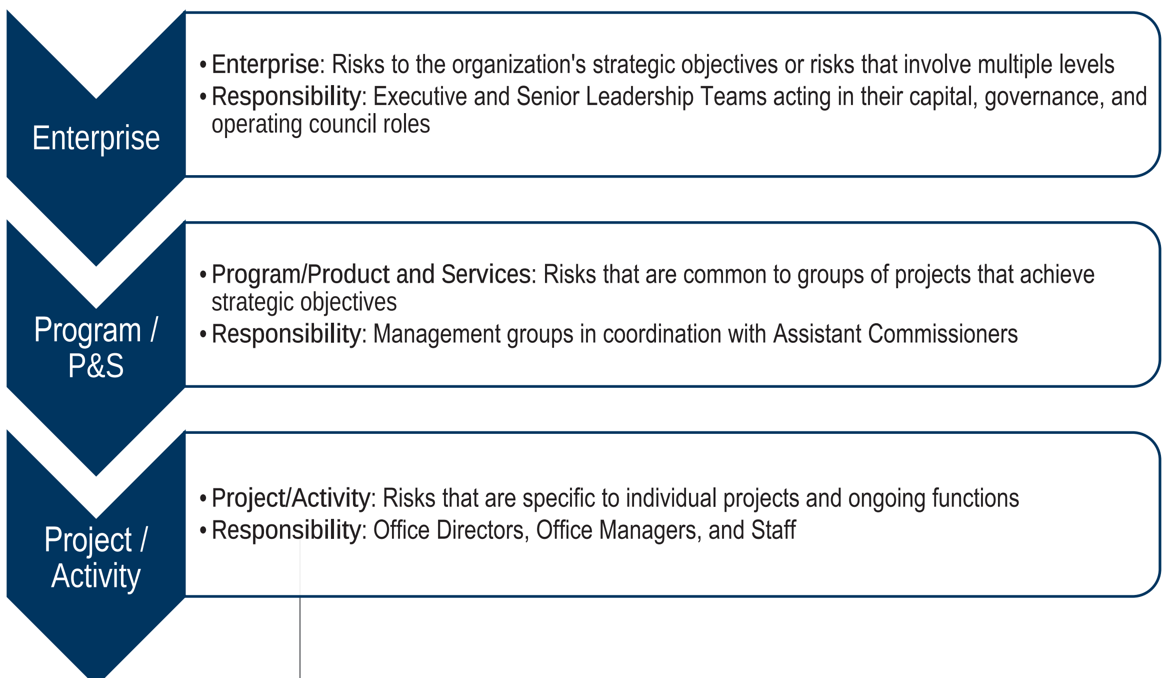
Risk at MnDOT

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

ENTERPRISE RISK MANAGEMENT

To help guide the transition to formal and universal consideration of risk, MnDOT has implemented an Enterprise Risk Management framework. The framework – illustrated in Figure 5-2 – establishes the standards, processes and accountability structure used to identify, assess, prioritize, and manage key risk exposures across the agency. The framework enables leaders and managers at all levels to systematically evaluate implications of decisions and actions to the agency's highest priority goals and objectives and effectively manage or control a broad array of risks in an informed and strategic manner. The uncertainty and variability associated with risks operates at multiple levels in an organization. Strategic objectives often cannot be achieved without coordination and understanding of risks at all levels. There are two key benefits to thinking of risks through the lens found in Figure 5-2. It identifies the impacts of risks within their context or scope and assigns responsibility of monitoring risks.

Figure 5-2: Levels of Risk Management MnDOT



MINNESOTA 20-YEAR STATE HIGHWAY INVESTMENT PLAN

Risk was a key factor considered during the 2018-2037 MnSHIP update. Risk-based planning was central to its development, as MnDOT systematically identified the likelihood and impact of different risks to assess the trade-offs associated with various investment levels across all of the assets. The resulting document guides MnDOT's future investment planning. The plan is updated every five years and performance progress is evaluated annually through the 10-year Capital Highway Investment Plan.

As a result of changes in performance requirements, targets and prioritization established by MAP-21 and continued with the passing FAST Act, MnDOT created two programs – the Statewide Performance Program and the District Risk Management Program. 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.

Figure 5-3: Key Investment Risks

KEY INVESTMENT RISKS	CURRENT	FUTURE (2037)
Federal Performance Requirements: Failure to achieve federal performance requirements on Interstate pavements and NHS bridges reduces flexibility to spend future revenue on other state priorities.	Low	Low
Remaining Service Life: The investment direction limits MnDOT's ability to perform the right fix at the right time, which leads to a decreased lifespan of the asset and more expensive fixes later.	Medium	High
Operations Budget: Maintenance costs rise, which places undue pressure on the operations budget and adds travel disruptions.	Medium	High
Increased costs to users: Poor asset management ultimately leads to increased costs to users of the system and Minnesota's economy by placing weight limitations on bridges.	Low	Medium
Safety Infrastructure: Critical traveler safety features begin to deteriorate, limiting their effectiveness.	Low	Low
Multimodal Priorities: Reduced investment in critical connections limits MnDOT's ability to advance modal priorities.	Medium	Medium
Mobility: Limited investment impacts mobility of people and goods which negatively impacts economic health.	Low	High
Urban Reconstruction: A focus on statewide performance measures and asset management results in lack of investment in urban reconstruction projects.	Medium	High
Responsiveness: Limited investment reduces MnDOT's ability to support local economic development and quality of life opportunities.	Medium	High
Climate Change: Inadequately addressing the effects of climate change and flooding leads to unplanned road closures and increased maintenance costs	High	High
Legislative Action: Misalignment between MnSHIP investment direction and legislative priorities results in legislation that redirects financial resources and compromises plan outcomes.	Medium	High

OPERATIONAL RISK MANAGEMENT

In addition to risk management of the capital program, MnDOT has also made great strides in assessing and reducing its risks for operations and maintenance. MnDOT has invested heavily to inventory its less prominent assets, such as ITS and lighting. This has been a holistic and comprehensive effort to measure asset condition and to place them in a management system. The work completed as part of the pilot TAMP highlighted low-cost actions that could be completed to reduce risk and improve traveler safety. Since 2014, these actions have been implemented and operationalized.

RESEARCH PROJECTS

The concept of risk also factors heavily into several completed research projects at MnDOT. While flooding is not the only threat to the state's highway system posed by climate change, it is likely to be one of the most significant and has already caused extensive disruptions to the transportation system in many areas. The agency completed an Extreme Flood Vulnerability Analysis and Adaptation Assessment Pilot Project that helps MnDOT (and other state DOTs) better understand the process for incorporating climate change into asset management planning. Regions in southeast and northeast Minnesota were selected in this analysis as they have experienced particularly extreme flooding in recent years. This project has helped inform future asset management decisions and initiatives related to climate change, hydraulic infrastructure such as culverts and bridges, and roadway susceptibility to extreme flood-related events. As a result of this project, MnDOT recently began a research implementation project to incorporate climate change vulnerability metrics into BRIM and TAMS.

MnDOT also completed a slope vulnerability study for the metro and southern Minnesota regions. As a result of this study, a slope vulnerability model was developed using geomorphology to assess impact to MnDOT roadways. The primary causes of slope failures in each region were identified, a Geographic Information System analysis applied these factors to the existing terrain, and a spatial output mapped vulnerable locations to be used in agency decision-making. This project is in the process of being applied statewide.

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 affect 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 5-4 illustrates MnDOT's risk rating scale. Figures 5-5 through 5-12 summarize the list of risks as identified by the asset work groups. 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. 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.

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. MnDOT concluded that current practices were already mindful of many global risks, and that the agency (and the public it serves) would therefore benefit most if the risk mitigation strategies 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 for all assets in the TAMP was presented to the Steering Committee for prioritization. Risks have since been identified for six additional assets. The asset-specific work groups, along with members of the TAMP Advisory Group and Asset Management Steering Committee, revisited risks from all assets in conducting a cross-asset risk workshop. The results are in Figure 5-13.

Figure 5-4: Risk Rating Matrix

CONSEQUENCE RATINGS	LIKELIHOOD RATINGS AND RISK LEVELS				
	RARE	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

Figure 5-5: Pavement and Bridge Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
Unexpected short-term funding reductions does not allow MnDOT to manage to the lowest life cycle cost	Moderate	Possible	Medium
*Not meeting public expectations for pavement quality/condition at the state/district/local levels**	*Moderate*	*Possible*	*Medium*
Inability to meet federal requirements	Major	Rare	Low
Significant reduction in funding over time	Minor	Possible	Low
*Inappropriately managing or not managing pavements such as frontage roads, ramps, auxiliary lanes, and rest areas due to lack of adequate infrastructure inventory and condition information**	*Minor*	*Possible*	*Low*
Premature deterioration of pavements due to construction issues, increase in traffic, higher equivalent single axle loads (ESALs) than designed for and snow and ice removal methods	Moderate	Possible	Medium
*Unexpected funding reductions does not allow MnDOT to manage to the lowest life cycle cost**	*Minor to Moderate*	*Likely*	*Medium*
*Premature deterioration of the asset**	*Moderate to Major*	*Unlikely*	*Medium*
Shortage of workforce	Minor to Moderate	Possible	Low to Medium
Catastrophic failure of the asset	Catastrophic	Rare	Medium
Significant damage to the asset through man-made or natural events	Major	Unlikely	Medium

*Undermanaged risks identified and prioritized in TAMP

Figure 5-6: Highway Culvert and Deep Stormwater Tunnel Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
*Failure/collapse of tunnel/culvert**	*Catastrophic*	*Likely*	*Extreme*
*Flooding and deterioration due to lack of tunnel/culvert capacity**	*Catastrophic*	*Possible*	*High*
Lack of culvert capacity, potentially resulting in adverse impacts to properties and roadway user safety	Minor	Almost Certain	Medium
*Inability to manage culverts to lowest life cycle cost**	*Moderate*	*Possible*	*Medium*
Difficulty to appropriately manage tunnels due to unexpected availability of funding	Moderate	Likely	Medium
Inappropriately distributing funds or inconsistency in culvert investments	Minor	Possible	Low
Significant damage to culverts through man-made events	Insignificant	Likely	Low

*Undermanaged risks identified and prioritized in TAMP

Figure 5-7: Overhead Sign Structures and High-Mast Light Tower Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
*Poor construction and/or installation**	*Minor*	*Likely*	*Medium*
*Inability to manage to lowest life cycle cost**	*Minor*	*Likely*	*Medium*
Significant damage to asset through man-made events	Minor	Likely	Medium
Premature deterioration of the asset	Minor	Likely	Medium
Unforeseen changes in regulatory requirements, travel demands or technology	Moderate	Rare	Low
*Shortage of workforce**	*Minor*	*Possible*	*Low*
Potential structural failure	Minor	Possible	Low

*Undermanaged risks identified and prioritized in TAMP

Figure 5-8: Noise Wall Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
Not repairing problems identified during inspection	Moderate	Possible	Medium
Not managing noise walls to lowest life cycle	Moderate	Possible	Medium
Not having a unified data management system results in an inconsistency for how walls are managed and inefficient use of resources	Minor	Likely	Medium
*Noise walls need to be inspected at appropriate frequencies to address fixes in a timely manner and to reduce the potential for a legislative audit**	*Moderate*	*Likely*	*Medium*
Not complying with federal reporting could result in rescinding of federal funding	Minor	Possible	Low
*Poor contract execution results in sub-par or out of compliance assets, which adds costs to MnDOT and creates a safety concern for public traveling along and adjacent to noise walls**	*Moderate*	*Possible*	*Medium*

*Undermanaged risks identified and prioritized in TAMP

Figure 5-9: Signals and Lighting Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
*Poor traffic signal timing results in increased traffic congestion and accidents**	*Moderate*	*Likely*	*Medium*
Poor construction and/or installation	Moderate	Likely	Medium
Light inoperability results in decreased safety benefits to the traveling public, negative perception of how MnDOT is managing its assets	Minor	Almost Certain	Medium
Light pole failure because of weather event, premature deterioration, or beyond service life results in a system that is unsafe for the traveling public and potential injury	Moderate	Possible	Medium
*Not managing assets appropriately results in premature deterioration and unforeseen traffic incidents and/or congestion**	*Moderate*	*Possible*	*Medium*

*Undermanaged risks identified and prioritized in TAMP

Figure 5-10: Building Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
*Inability to manage buildings appropriately/efficiently**	*Moderate*	*Almost Certain*	*High*
*Lack of dedicated capital and maintenance funding**	*Major*	*Likely*	*High*
Increasing maintenance equipment size, including tow plows	Moderate	Likely	Medium
Temporary or permanent rest area closures	Major	Likely	High

*Undermanaged risks identified and prioritized in TAMP

Figure 5-11: ITS Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
*System design, construction issues or system flaws (vulnerability)**	*Moderate*	*Likely*	*Medium*
*Inadequate operations/maintenance funding and staff**	*Moderate*	*Likely*	*Medium*
Not identifying an appropriate responsible party for maintenance/ operations	Moderate	Possible	Medium
Ineffective (poor) vendor accessibility, communication or relationship	Moderate	Possible	Medium
Technology shift/obsolescence	Moderate	Possible	Medium
Extreme weather	Moderate	Likely	Medium

*Undermanaged risks identified and prioritized in TAMP

Figure 5-12: Pedestrian Infrastructure Risks Identified by Asset Work Groups

RISKS	CONSEQUENCE	LIKELIHOOD	OVERALL RISK RATING
*Not meeting the needs of system users, including the disabled community**	*Major*	*Likely*	*High*
Not meeting federal compliance or the intent of ADA	Major	Possible	Medium
Poor planning, design and/or construction	Moderate	Likely	Medium
Failure to comply with Complete Streets Policy	Moderate	Likely	Medium
*Failure to address system gaps with future funding**	*Moderate*	*Likely*	*Medium*
*Not receiving local consent/agreement results in a lack of operations/maintenance and oversight that leads to premature deterioration**	*Moderate*	*Likely*	*Medium*

*Undermanaged risks identified and prioritized in TAMP

Figure 5-13 identifies the risk mitigation strategies identified by the expert work groups, separated into three priority levels based on factors like need, ease of implementation and ability to reduce the perceived risk. The TAMP Advisory Group and Asset Management Steering Committee prioritized mitigation strategies based on factors such as influence on risk rating before and after implementation, impact on the agency, and cost of implementation. Chapter 9: Implementation and Future Developments provides more detail for these priorities, including purposes, responsible parties, expected time frames and estimated implementation costs.

Figure 5-13: 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: Investigate the likelihood and impact of deep stormwater tunnel system failure
- Overhead Sign Structures and High-Mast Light Tower Structures: Track in a Transportation Asset Management System
- ITS: Develop a statewide ITS system sample plan and standard details/specification, including performing integration (built on the ITS Design Manual)
- Traffic Signals and Lighting: Develop retiming schedule for statewide traffic signals
- Traffic Signals and Lighting: Develop a Transportation Research Synthesis on preventive maintenance in other agencies
- Traffic Signals and Lighting: Develop a statewide traffic signal and lighting checklist for construction project engineers and/or inspectors to use when signing off during construction and after completion
- Buildings: Conduct a study to determine operation deficiencies, site condition, and future needs for gap assessment (used for scoping and project prioritization process)
- Buildings: Implement Archibus and develop a project prioritization process for existing as well as any new funding

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
- Highway Culverts: Provide support, tools, and reports for management of highway culverts in TAMS
- Overhead Sign Structures: Develop a policy requiring a five-year inspection frequency, as well as related inspection training programs and forms
- Traffic Signals and Lighting: Identify optimal preventive maintenance protocols for lighting, including a resource demand model (i.e., materials, parts, etc.), and/or TRS on preventive maintenance
- Pedestrian Infrastructure: Develop an inspection/cycle protocol based on condition or age and TAMS. The protocol includes ADA ramps, curbs, sidewalks, and other pedestrian infrastructure needs (include: frequency, who is responsible for activities, costs, and other pertinent information)
- Noise Walls: Develop an inspection/maintenance cycle protocol to identify which noise walls should be inspected/maintained, including a staffing need/gap assessment based on inspection/maintenance protocols
- Noise Walls: Conduct education/training and a construction sign-off (i.e., liaison) or contract compliance protocol

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
- ITS: Develop an inspection/maintenance cycle protocol to identify what ITS assets should be inspected/maintained, including a staffing need/gap assessment based on inspection/maintenance protocols
- Traffic Signals and Lighting: Develop a statewide resource demand model for signal re-timing (personnel, consultant contracts, etc.)
- Traffic Signals and Lighting: Develop and increase staffing resources with proficient knowledge to be able to extract and use information from TAMS to better manage the assets
- Pedestrian Infrastructure: Identify and integrate pedestrian measures, targets, and needs into MnSHIP and MnDOT program delivery process
- Pedestrian Infrastructure: Develop an ADA/pedestrian guide that identifies the appropriate process (i.e., consent agreement), types of ADA/complete streets improvements by corridor, urban-rural, etc.

Emergency Response Events

As a part of final rule making, FHWA requires state DOTs to conduct periodic evaluations of facilities that repeatedly require repair and reconstruction due to the occurrence of emergency events. The purpose of this evaluation is to conserve federal resources and protect public safety by determining if reasonable alternatives exist to roads, highways, or bridges that repeatedly require repair and reconstruction activities.

MnDOT did not have a comprehensive electronic system in place with all necessary data to initially conduct this analysis. This requirement resulted in the development of a system, which contains a list of projects that have used emergency response funds from January 1997 to March 2017. Best available data was extracted from Detailed Damage Inspection Reports, the Program and Project Management System, the Fiscal Management Information System and other project description documents or systems. Data was then mapped using Geographic Information System software. A spatial analysis produced a list of locations where project locations overlapped.

Below is a list of emergency events that required the use of emergency relief funds:

- Washout flood events
- Erosion caused by flooding
- Bridge replacement/reconstruction
- Debris removal
- Guardrail replacement
- Slope repair
- Culvert/sewer/drainage structure repair
- Shoulder repair
- Ditch erosion

There were several projects that required an evaluation for the use of emergency relief funds. Projects that had two or more line items included work that was completed on different beginning and end mile points for the same project identification number in FMIS. However, the data indicated that there were not any facilities that required the use of emergency relief funds beyond the fiscal year in which it was affected by an emergency event.

This analysis concluded that further evaluation is not necessary due to no roads, highways or bridges requiring repair on two or more occasions due to an emergency event.

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Chapter 6

LIFE CYCLE PLANNING

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LIFE CYCLE PLANNING

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. MnDOT and its partners work 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.

MnDOT's Life Cycle Planning objectives are to:

- Establish a long-term focus for improving and preserving the system
- Develop maintenance strategies that consider long-term investment needs
- Determine the funding needed to achieve the desired state of good repair
- Determine the conditions that can be achieved for different levels of funding
- Reduce the annual cost of system preservation without impacting asset conditions
- Provide objective data to support investment decisions
- Eliminate existing performance gaps
- Demonstrate good stewardship to internal and external stakeholders

MnDOT attempts to accomplish these objectives through three major phases of management of its system:

- Performance-based, long-range planning (capital planning at the network level)
- Life cycle cost-based project design alternative selection
- Life cycle cost-based management strategies

Each of these approaches will be described in this chapter.

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.

Life Cycle Planning

Life Cycle Planning, as defined by FHWA, is “a process to estimate the cost of managing an asset class, or asset sub-group, over its whole life with consideration for minimizing cost while preserving or improving the condition." Life Cycle Planning 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. A question that Life Cycle Planning hopes to answer is: which investments, made today, are most cost-effective in the long-term to keep the infrastructure in service for as long as feasibly possible?

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 Life Cycle Planning. It should be noted, however, that operational expenses and other indirect costs form a large part of the overall cost of asset ownership and can be impacted by asset design decisions. Collectively, governance, maintenance, operations, electricity and other indirect costs associated with transportation assets comprise total cost of ownership. As an example, MnDOT spends between $80 million and $150 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.

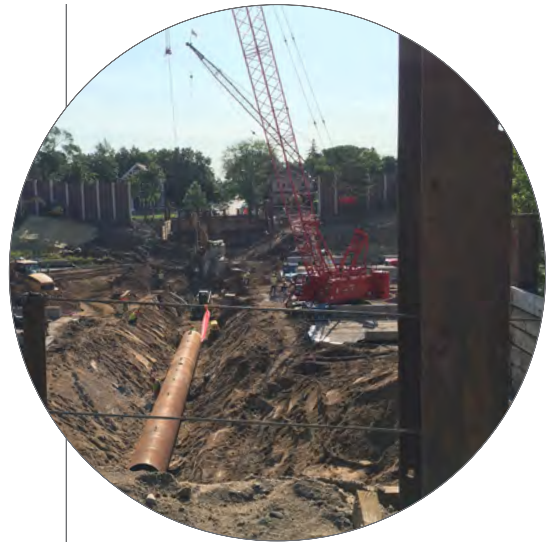
The state seeks to limit life cycle costs to the greatest extent possible. Limiting or postponing future costs allows unused funds to be invested elsewhere in the system. MnDOT’s policy is to analyze all investments using a real annual discount rate which is currently set at 1.2 percent. The term “real” means that the effects of inflation are removed from the computation in order to make the cost trade-offs easier to understand.

Although it is attractive to delay incurring preventive maintenance costs as much as possible in order to take advantage of the discount rate, doing so will typically only result in increased costs over time. 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 Life Cycle Planning are:

- Planning Period: the time-frame over which the Life Cycle Planning is performed
- Life Cycle Cost (in today's dollars): the total cost to build, inspect, maintain, replace, and dispose of an asset over the analysis period when the costs incurred in future years are converted to current dollars
- Equivalent Uniform Annual Cost: the average yearly cost to maintain an asset

The following sections discuss the three major processes by which MnDOT seeks to optimally manage its infrastructure.



Performance-Based Long-Range Planning

MnDOT makes investment decisions based on a series of plans which establishes direction and communicates its priorities. Beginning with its long-range plan called Minnesota GO, which describes its 50-year vision, its Statewide Multimodal Transportation Plan, which describes investments and interaction between transportation modes, and its Minnesota State Highway Investment Plan, which addresses programmatic and project level investments over a 20-year planning horizon, MnDOT maintains a long-term focus as investment decisions are made.

MnSHIP directly relates to asset management objectives by addressing trade-offs between investment areas such as mobility, safety, and asset management--by assessing the department's ability to meet performance objectives through the analysis of multiple investment scenarios.

The investment direction presented in MnSHIP prioritizes investments to maintain the existing state highway pavements and bridges while making limited mobility improvements over the next 20 years. The direction will guide investments so that transportation projects align with statewide goals as much as possible with available funding. MnDOT's planning processes are described in more detail in Chapter 2: Asset Management Planning and Programming Framework.

DEVELOPMENT OF INVESTMENT APPROACHES IN MNSHIP

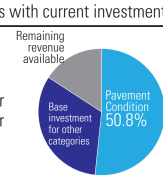
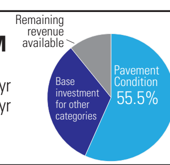
Maintaining existing infrastructure at today's condition levels for the next 20 years would require nearly all $21 billion of MnSHIP's available revenue. Given the limited revenue, MnDOT identified investment trade-off decisions that balance numerous competing priorities. To illustrate these trade-off decisions, MnDOT developed performance levels for each investment category and then packaged different performance levels from each category into three investment approaches.

These performance levels represented, in broad terms, concepts such as:

- Minimum maintenance only
- Minimally meet performance requirements
- Maintain current investment levels
- Reduced funding scenarios

Forecasts of performance-level outcomes are made using MnDOT's Highway Pavement Management Application and Bridge Replacement and Improvement Management systems. As described in Chapter 2, each system is capable of generating investment scenarios and forecasting the network level system conditions that would result. Both pavement and bridge management systems include the expectation that preventive maintenance activity schedules will be followed. HPMA includes algorithms that prioritize projects based on “Marginal Cost Effectiveness” to optimize return on investment. BRIM relies on the outcome of a separately validated benefit cost analysis to set proposed project scope at an optimum level.

Figure 6-1: Pavement Condition Investment Category Folio

	Performance Level 0 *Lowest cost, greatest risk*	**Performance Level 1** *Lower cost, higher risk*
Investment Approach *(See Approach Folio)*	**Approach C** Corresponds with current investment	**Approach A, B**
Investment Level *Total* *Years 5-10 (2022-2027)* *Years 11-20 (2028-2037)*	**$8,447 M** $527.9 M/yr $527.9 M/yr  	**$9,242 M** $577.6 M/yr $577.6 M/yr 
Investment Description	Maintain current investment direction based on 2013 MnSHIP investment direction	Maintain Interstate at a level compliant with MAP-21. Maintain GASB 34 threshold on the NHS and Non-NHS system.

In MnSHIP, each category had three to five performance levels (level 0 to level 2, 3 or 4). MnDOT used both performance measures and risk to define a potential range of investment in each category. The lowest performance level, PL 0, represents the minimum level of investment that is acceptable given

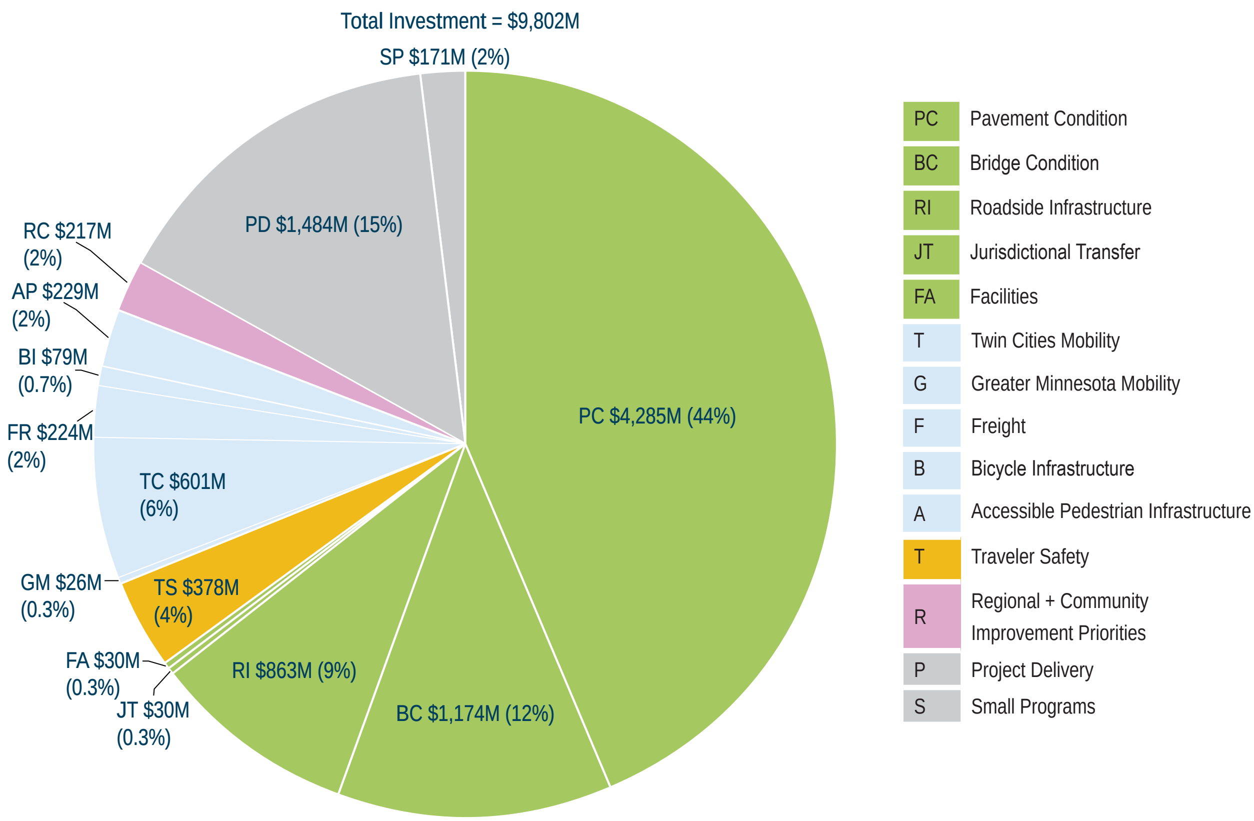
MnDOT's responsibility for public safety and basic system functionality. The highest investment levels allow MnDOT to meet the goals and objectives for each investment category and to make more progress toward the Minnesota GO vision. Each performance level corresponds with a different set of improvements, outcomes, risks, and risk management strategies.

INVESTMENT SUMMARY

The 20-year investment direction focuses on maintaining the existing state highway system while making limited mobility investments. This approach reflects MnDOT and stakeholder input and meets key requirements and agency commitments. It also continues a shift for MnDOT from being a builder of the system to the maintainer and operator of the system. The investment direction does not affect the projects already developed and programmed in years 2018 through 2021. The priorities identified in MnSHIP will be reflected in investments and projects starting in 2022. Figure 6-2 shows the distribution of expenditures from 2018-2027, the years covered in the TAMP.

MnDOT makes investment-level decisions for pavements on a network basis during MnSHIP preparation and allocates funding to the districts which are charged with selecting projects that will meet MnSHIP outcomes. MnDOT believes that the local knowledge of system nuances is a critical component of good decision-making, yet in years past analytical tools to evaluate these local

Figure 6-2: 10-Year Capital Highway Investment Distribution from 2018-2027



decisions have not been readily available. Starting in 2018, MnDOT developed a Pavement Investment Guide to support district decision-making. The guide is intended to take investment optimization to the next level by providing investment guidance and several new measures/indicators for districts to evaluate strategies. The indicators will include the following:

- % Poor
- % Good
- Remaining Service Life
- Asset Sustainability Ratio
- Asset Value
- Preventive maintenance % of optimum

Modifications are being made to MnDOT's HPMA which will allow District Materials Engineers to easily create district investment scenarios and evaluate them against the suite of indicators. MnDOT believes that providing additional information and tools will result in further optimization of pavement investments.

Life Cycle Cost Based Project Alternative Selection

MnDOT makes project level scoping investment decisions that consider life cycle costs in particular for pavement and bridge projects. For significant pavements projects, a "Pavement Determination" is made which considers a full analysis of life cycle costs to choose between rigid and flexible pavements. Software is provided to districts to further refine designs with variables such as local materials costs tailored to regional conditions. For bridge design decisions, MnDOT uses a comprehensive deterministic model that distinguishes between (up to six) design alternatives and compares long-term costs to maintain the structure.

As a result of recent improvements in the availability of asset and costing information, MnDOT is beginning to analyze other selected asset decisions on an ad hoc basis. For example, improved knowledge about life expectancy of noise walls can be considered against costs of alternatives, or selection of culvert materials can be tailored to local soil acidity in consideration of MnDOT's maintenance costs.

Though not uniform or consistent, this represents a rapidly emerging practice within MnDOT as the inventory of assets is completed, and cost data is gathered and modeled. One of MnDOT's goals for its asset management program is better integration of capital and maintenance investment decisions.

Life Cycle Based Management Strategies

The third component of MnDOT's effort to minimize life cycle costs is through consideration of life cycle management strategies for individual asset classes, incorporating treatments suggested by the management systems, and respective costs that include both capitally funded actions as well as preventive and reactionary work accomplished by MnDOT's maintenance staff.

During the development of MnDOT's pilot TAMP, life cycle cost analyses were prepared for several asset classes using either deterministic modeling techniques or Markov Chain network level analyses. The analyses generally considered "worst first" theoretical strategies (run-to-failure) to other management scenarios representing judgments about current and ideal practices.

One of MnDOT’s stated goals for this TAMP is that it be helpful and useful to operational decision makers. To that end, the “worst first” theoretical strategies have been replaced by “minimum maintenance” scenarios which reflect plausible, if less than optimum, deferred maintenance approaches. The strategies are described through the presentation of treatments and associated timing in the tables presented later in this chapter.

Since preparation of the pilot TAMP, MnDOT has improved its ability to model internal maintenance costs for routine, reactive, and preventive maintenance in accordance with asset condition, and has been able to update the life-cycle models accordingly. These models give asset owners an order of magnitude representation of possible savings or efficiencies to be gained through application of best practices, and in some cases, an indication of performance advantages.

In 2019, the Minnesota Office of the Legislative Auditor published a report recommending that MnDOT seek to better quantify both internal and capital cost trade-offs, as well as user cost related to decision-making. In response, a modeling process designed to monetize delay associated with pavement work was created, and variations in the results can be seen. Models for bridge and other traffic impacting activities have not yet been created.

MnDOT has also developed a draft asset management policy to further tie the recommendation of asset expert offices, investment decision makers and maintenance practitioners to optimize efficiency.

LIFE CYCLE PLANNING/LIFE CYCLE COST ANALYSES

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 it reaches the end of its useful life. Life Cycle

Planning depends on the ability to forecast both asset condition and future treatment costs. It uses economic treatments (discounting) to reduce all future costs to current dollars, so that different alternatives can be compared. 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. In best practice, the analysis period of Life Cycle Planning should satisfy 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 analyses conducted also compute remaining capital value, or residual value, and adjust the life cycle costs to preserve the comparability of alternatives. The following analysis periods have been used in the Life Cycle Planning:

- Pavements: A 70-year analysis period has been chosen to account for at least one complete reconstruction activity which is timed in response to varying investment and preventive maintenance approaches during the estimated lifespan for each of the analyzed treatments.
- Bridges, culverts and deep stormwater tunnels: These assets have life spans 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 analysis period is used for this longer-lasting asset category.
- **Overhead sign structures, high-mast light tower structures, traffic** signals, and roadway lighting: An analysis period of 50 years was chosen based on expert judgment of the life of these structures and the degree to which treatment options affect the estimated life.
- Noise Walls: An analysis period of 120 years was chosen based on expert judgment of the life of these structures and the degree to which treatment options affect the estimated life.
- Pedestrian Infrastructure: An analysis period of 35 years was chosen for curb ramps and 60 years for sidewalks based on expert judgment of the life of these structures and the degree to which treatment options affect the estimated life.

- ITS Infrastructure: Each sub-asset in ITS infrastructure has a different life span so it would be difficult to use one common analysis time frame for all ITS Infrastructure. In the example of dynamic message signs, an analysis period of 15 years was chosen based on expert judgment of the life of this asset.

A key goal of a Life Cycle Planning effort is to manage assets at the optimal level of preservation where life cycle costs are kept to a minimum. The Life Cycle Planning modeling strategies presented in the TAMP are summarized in relation to each asset discussed in this section. The analyses generally compare a minimum maintenance strategy to strategies that employ more aggressive preventive maintenance approaches. While they may be exemplary or network-wide in scope, the analyses give decision makers an indication of the savings that can be realized by either adopting or maintaining an aggressive preventive maintenance approach, attendant performance advantages, and user costs.

Typically, a bridge or pavement maintained at a level that minimizes costs long-term, is also kept in relatively good condition and produces a higher level of service over its life, which provides tangible benefits to both the agency and users.

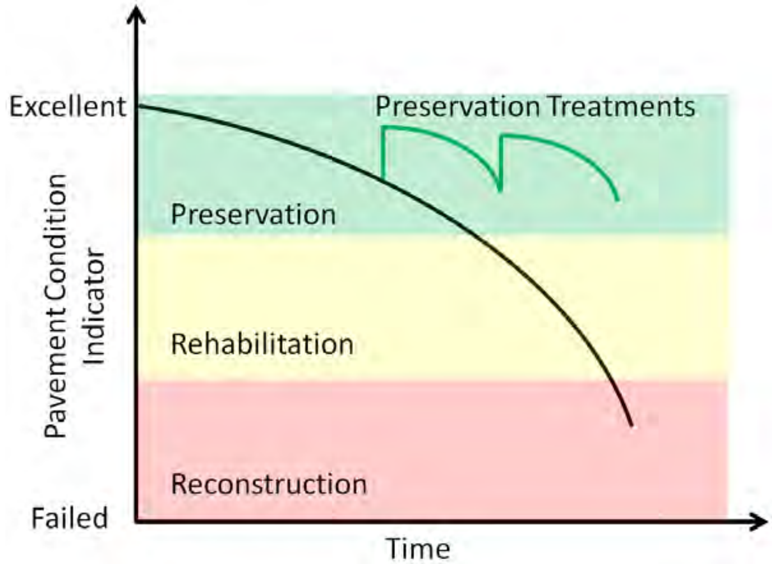
PAVEMENTS

As discussed in Chapter 1 and Chapter 4, MnDOT maintains a system of more than 14,000 roadway-miles of pavements statewide. The current replacement values of NHS and non-NHS pavements are approximately $16 billion and $14 billion, respectively. These high values demonstrate the need for a sound framework and methodology to managing these assets to the lowest life cycle cost.

Pavements deteriorate over time due to environmental factors and vehicle 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. Pavements can be managed on a continuum between simply building and providing minimum maintenance-only to implementing an aggressive preventive maintenance scenario. A typical pavement deterioration model demonstrating the impact of preservation is illustrated in Figure 6-3. Through the application of life cycle cost analyses, MnDOT has been able to objectively determine that it is not only cheaper to maintain its pavements through application of preventive maintenance actions, but that the quality of the pavements, and thus service to users, remains higher over time.

MnDOT has been increasing the amount of pavement preservation over the last decade and has taken active steps to maximize the implementation of preventive maintenance such as:

Figure 6-3: Deterioration Model Illustrating Impact of Preservation



- Creating a pavement preventive maintenance manual
- Staffing a temporary liaison to work between the Materials Office and districts
- Building preventive maintenance treatments into its Pavement Management System decision trees
- Developing a Pavement Investment Guide, and modifying pavement management software to allow districts to analyze investment scenarios unique to their local areas
- Assigning the Asset Management Program Office responsibility to work between the Materials Office and district maintenance and materials staff to improve the systematic planning of pavement preventive maintenance activities
- Development of illustrative materials such as a crack sealing exhibit which shows high benefits resulting from the work MnDOT employees can perform very cost effectively, to encourage pride in performing this sort of work
- Beginning to incorporate calculated internal maintenance cost implications related to MnSHIP performance scenarios as part of the capital programming process

Although they operate in a decentralized decision-making environment, most MnDOT districts proactively implement strong pavement preservation programs, though MnDOT currently lacks robust preventive maintenance tracking data. Also, the districts are required to manage their entire construction program within their budget. Unforeseen events such as project cost over-runs sometimes result in a reduction to the preventive maintenance funding.

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), asphalt mill and overlays and full-depth reclamation. Typical preservation and rehabilitation treatments on concrete-surfaced pavements include joint resealing, partial depth repairs, and minor/major concrete pavement repairs (e.g., dowel bar retrofit, diamond grinding, full-depth repairs). While some of these treatments 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 (e.g., 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.

Figures 6-4 through Figure 6-10 describe strategies and related costs for maintaining pavements according to the scenarios shown. MnDOT determined two pavement subgroups - flexible (bituminous) and rigid (concrete). Figure 6-4 summarizes the two rigid pavement scenarios while Figure 6-5 summarizes the three flexible pavement scenarios. Figures 6-6 through 6-10 show each scenario in more detail.

These exhibits are generic representations of the analyses' process, treatment sequences which may be compared, relative costs thereof, and resulting life-cycle costs. For bituminous pavements – relative condition outcomes and user costs can also be recognized. Note that the analyses are sensitive to many assumptions that must be made. For one, the theoretical analyses begin at year zero of a pavement lifespan. In reality, the beginning age and condition vary with each road segment. In keeping with MnDOT's Pavement Investment Guide, district engineering staff are encouraged to take advantage of these tools in actual situations where variables (such as starting condition, design, and history) are better known and outputs can be tailored to specific questions.

RIGID PAVEMENT

To give decision makers a frame of reference for the annual cost of owning rigid pavements, a life cycle costing exercise was performed for two rigid pavement scenarios. The roadway section may represent a fairly heavily travelled rural two-lane concrete expressway. The "Minimum Maintenance" strategy assumes a nominal cost of reactive maintenance on a three-year interval, plus the assumption of two un-bonded overlays during the 70-year life. An alternative which seeks to forestall major pavement replacement through more aggressive preventive maintenance, as shown in MnDOT's Pavement Design Manual, is presented as well. Costs are as indicated, with the postponing of major pavement renewal offering a significant savings. Again, decision makers are encouraged to utilize analytical tools with local data to support trade-offs.

Figure 6-4: Rigid Pavement Life Cycle Planning Scenarios

DEFINED ACTIVITY	RIGID PAVEMENT ACTIVITY	TYPICAL COSTS PER LANE MILE	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B PAVEMENT DESIGN MANUAL
Typical Maintenance	Maintenance	$2,380-$5,230	21 times during life cycle	19 times during life cycle
Reseal joints and partial depth repair	Preservation	$10,000	Not applied	Not applied
Minor CPR (some full depth repairs)	Preservation	$71,670	Not applied	1 time during life cycle
Major CPR (and grinding)	Preservation	$198,330	Not applied	2 times during life cycle
Unbonded Overlay	Major Rehabilitation	$544,906	2 times during life cycle	Not applied
MNDOT EUAC (COST PER LANE MILE)	N/A	ANNUAL	$21,170	$18,940

*Pavement van evaluates pavement condition on an annual basis statewide.

FLEXIBLE PAVEMENT

The following example pavement section for LCCA may be representative of a mid-volume two-lane rural bituminous roadway (the user cost computations assume 3,000 AADT). Three alternatives are presented: “Minimum Maintenance,” where very little beyond reactive patching is done later in the pavement life. A second scenario – “PDM” is a direct application of the recommendations in the MnDOT Pavement Design Manual. The third represents an evaluation of a strategy proposed by a MnDOT pavement engineer (as promoted by this chapter) to use an aggressive preventive maintenance strategy in conjunction with progressively deeper repairs correlating to anticipated depth of pavement cracking.

Costs are as indicated, with the usage of the MnDOT Pavement Manual showing 5 percent savings given the assumptions in the exercise. Of note is the substantial difference in pavement service and notable difference in user costs. Decision makers are encouraged to use these analytical tools, in addition to varying user cost inputs to assess the sensitivity of the outputs.

KEY TAKEAWAYS

The analysis suggests that EUAC can be reduced significantly, or performance can be increased, and user costs reduced by using preventive maintenance in keeping with MnDOT’s Pavement Design Manual.

The analyses are sensitive to certain assumptions and districts are encouraged to use these tools, in support of the Pavement Investment Guide, by customizing variables to reflect the unique situations faced. User costs can also be considered with this simple model. Varying the assumptions can easily highlight sensitivity to input variables.

Figure 6-5: Flexible Pavement Life Cycle Planning Scenarios

DEFINED ACTIVITY	FLEXIBLE PAVEMENT ACTIVITY	TYPICAL COST PER LANE MILE	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B PAVEMENT DESIGN MANUAL	STRATEGY C LEVEL OF SERVICE
Patching	Reactive Maintenance	$1,000-$3,800	18 times during life cycle	Not applied	Not applied
Chip Seal	Preservation	$18,000	Not applied	4 times during life cycle	4 times during life cycle
Crack Treatment	Preservation	$3,000	Not applied	4 times during life cycle	6 times during life cycle
Micro-Mill & Surface Treatment	Preservation	$55,000	Not applied	Not applied	2 times during life cycle
Microsurfacing	Preservation	$30,000	Not applied	Not applied	2 times during life cycle
Thin Mill and Overlay	Preservation	$100,000	Not applied	Not applied	2 times during life cycle
Medium Mill and Overlay	Preservation	$165,000	Not applied	4 times during life cycle	1 time during life cycle
New Hot Mix Asphalt	Major Rehabilitation	$469,272	1 time during life cycle	1 time during life cycle	1 time during life cycle
Cold In-Place Recycling & Overlay / Thick Mill & Overlay	Major Rehabilitation	$180,000	Not applied	Not applied	1 time during life cycle
Reclaim and Overlay	Major Rehabilitation	$240,000	3 times during life cycle	Not applied	Not applied
LEVEL OF SERVICE (SURFACE RATING)	N/A	N/A	AVERAGE - 3.2 MINIMUM - 2.4	AVERAGE - 3.6 MINIMUM - 3.0	AVERAGE - 3.7 MINIMUM - 3.1
MNDOT EUAC (COST PER LANE MILE)	N/A	ANNUAL	$12,560	$12,000	$12,440
USER DELAY EUAC (COST PER LANE MILE)	N/A	ANNUAL	$5,130	$1,840	$1,890

Figure 6-6: Minimum Maintenance Scenario Life Cycle Management Strategy for Flexible Pavements

TYPICAL PAVEMENT AGE* (YEARS)	ACTIVITY TYPE	TYPICAL CONDITION WHEN APPLIED	TYPICAL COST (PER LANE MILE)**	DISCOUNTED TOTAL DELAY COST PER LANE MILE
0	New HMA	-	$469,272	$122,250
13	Patching	Good	$1,437	$300
15	Patching	Good	$1,401	$298
16	Patching	Good	$1,383	$298
17	Patching	Good	$1,365	$297
18	Patching	Good	$1,347	$296
19	Patching	Fair	$1,956	$295
20	Reclaim and Overlay	Poor	$185,363	$104,323
33	Patching	Good	$1,110	$283
35	Patching	Good	$1,082	$281
36	Patching	Good	$1,068	$281
37	Patching	Good	$1,054	$280
38	Patching	Fair	$1,530	$279
39	Patching	Fair	$1,511	$278
40	Reclaim and Overlay	Poor	$143,164	$89,025
53	Patching	Good	$857	$267
55	Patching	Good	$835	$265
56	Patching	Good	$825	$265
57	Patching	Good	$814	$264
58	Patching	Fair	$1,182	$263
59	Patching	Fair	$1,167	$262
60	Reclaim and Overlay	Poor	$110,572	$75,971
70	Residual Value (10/20 years used)	Good	-$48,587	($37,985)
TOTAL PRESENT WORTH	N/A	N/A	$881,707	$359,412
MNDOT EUAC	N/A	N/A	$12,596	N/A
TOTAL USER DELAY EUAC	N/A	N/A	$5,134	N/A

Note:
* Based on values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT Pavement Work Group
**Cost data provided by MnDOT TAMP Pavement Work Group

Figure 6-7: Pavement Design Manual Scenario Life Cycle Management Strategy for Flexible Pavements

TYPICAL PAVEMENT AGE* (YEARS)	ACTIVITY TYPE	TYPICAL CONDITION WHEN APPLIED	TYPICAL COST (PER LANE MILE)**	DISCOUNTED TOTAL DELAY (COST PER LANE MILE)
0	New HMA	-	$469,272	$122,250
8	Crack Treatment	Good	$2,705	$203
12	Chip Seal	Good	$15,416	$201
20	Medium Mill and Overlay	Good	$127,437	$1,176
23	Crack Treatment	Very Good	$2,229	$777
27	Chip Seal	Good	$12,700	$192
37	Medium Mill and Overlay	Good	$102,314	$1,119
40	Crack Treatment	Very Good	$1,790	$185
44	Chip Seal	Good	$10,197	$183
54	Medium Mill and Overlay	Good	$82,144	$1,064
57	Crack Treatment	Very Good	$1,437	$176
61	Chip Seal	Good	$8,186	$174
70	Medium Mill and Overlay	Good	$66,807	$1,015
70	Residual Value (1/15 years used)	Very Good	-$62,353	($948)
TOTAL PRESENT WORTH	N/A	N/A	$840,280	$127,767
MNDOT EUAC	N/A	N/A	$12,004	N/A
TOTAL USER DELAY EUAC	N/A	N/A	$1,825	N/A

Note:
*Based on values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAP Pavement Work Group
**Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions made to develop cost ranges based on data provided

Figure 6-8: Level of Service Scenario Life Cycle Management Strategy for Flexible Pavements

TYPICAL PAVEMENT AGE* (YEARS)	ACTIVITY TYPE	TYPICAL CONDITION WHEN APPLIED	TYPICAL COST (PER LANE MILE)**	DISCOUNTED TOTAL DELAY (COST PER LANE MILE)
0	New HMA	-	$469,272	$122,250
2	Chip Seal	Very Good	$17,541	$207
9	Crack Treatment	Good	$2,671	$202
13	Micro-Mill & Surface treatment	Good	$46,499	$400
17	Crack Treatment	Very Good	$2,409	$198
23	Thin Mill and Overlay	Good	$74,299	$777
26	Crack Treatment	Very Good	$2,144	$193
27	Chip Seal	Very Good	$12,700	$192
31	Microsurfacing	Very Good	$20,101	$190
38	Medium Mill and Overlay	Good	$101,001	$1,116
41	Crack Treatment	Very Good	$1,767	$184
42	Chip Seal	Very Good	$10,463	$184
48	Micro-Mill & Surface Teatment	Very Good	$29,588	$361
50	Crack Treatment	Very Good	$1,573	$179
57	Thin Mill and Overlay	Good	$47,892	$703
59	Crack Treatment	Very Good	$1,400	$175
60	Chip Seal	Very Good	$8,293	$174
63	Microsurfacing	Very Good	$13,296	$173
69	CIR & OL / Thick M&O	Very Good	$73,828	$42,443
70	Residual Value (2/20 years used)	Very Good	-$65,592	($38,199)
TOTAL PRESENT WORTH	N/A	N/A	$871,143	$132,102
MNDOT EUAC	N/A	N/A	$12,445	N/A
TOTAL USER DELAY EUAC	N/A	N/A	$1,887	N/A

Note:
*Based on values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAP Pavement Work Group
**Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions made to develop cost ranges based on data provided

Figure 6-9: Minimum Maintenance Scenario Life Cycle Management Strategy for Rigid Pavements

TYPICAL PAVEMENT AGE* (YEARS)	ACTIVITY TYPE	TYPICAL COST (PER LANE MILE)**
0	Initial Construction	$966,670
3	Maintenance	$2,886
6	Maintenance	$2,776
9	Maintenance	$2,671
12	Maintenance	$2,569
15	Maintenance	$2,472
18	Maintenance	$2,378
21	Maintenance	$2,287
24	Maintenance	$2,200
27	Maintenance	$2,117
30	Unbonded Overlay	$369,861
33	Maintenance	$1,959
36	Maintenance	$1,884
39	Maintenance	$1,813
42	Maintenance	$1,744
45	Maintenance	$1,678
48	Maintenance	$1,614
51	Maintenance	$1,553
54	Maintenance	$1,494
57	Maintenance	$1,437
60	Unbonded Overlay	$251,047
63	Maintenance	$1,330
66	Maintenance	$1,279
69	Maintenance	$1,230
70	Residual value (10/30 years used)	-$147,085
TOTAL PRESENT WORTH	N/A	$1,481,862
MNDOT EUAC (COST PER LANE MILE)	N/A	$21,169

Note:
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
**Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions made to develop cost ranges based on data provided

Figure 6-10: Preventive Maintenance Scenario Life Cycle Management Strategy for Rigid Pavements

TYPICAL PAVEMENT AGE* (YEARS)	ACTIVITY TYPE	TYPICAL COST (PER LANE MILE)**
0	Initial Construction	$966,670
3	Maintenance	$2,290
6	Maintenance	$2,203
9	Maintenance	$2,119
10	Reseal joints and partial depth repair	$8,788
13	Maintenance	$2,012
16	Minor CPR (some full depth repairs)	$58,289
19	Maintenance	$2,723
22	Maintenance	$2,619
26	Maintenance	$2,487
28	Major CPR (and grinding)	$138,141
31	Maintenance	$3,504
34	Maintenance	$3,371
37	Maintenance	$3,243
40	Maintenance	$3,120
43	Maintenance	$3,001
46	Maintenance	$2,887
50	Major CPR (and grinding)	$103,972
53	Maintenance	$2,638
56	Maintenance	$2,537
60	Maintenance	$2,410
63	Maintenance	$2,318
66	Maintenance	$2,230
69	Maintenance	$2,145
70	Residual value (20/20 years used)	$0
TOTAL PRESENT WORTH	N/A	$1,325,717
MNDOT EUAC (COST PER LANE MILE)	N/A	$18,939

MnDOT will also consider implementing more robust network level life cycle cost assessment approaches as research and technologies advance and are available (see Chapter 9). This work may be pursued during the next TAMP update cycle.

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 10 feet or greater in diameter (and some important smaller culverts) are inspected and managed as bridges. The bridges addressed in this TAMP (NHS, non-NHS, bridge culverts) have a replacement value of approximately $14.6 billion. The service life of most bridges is beyond 50 years and MnDOT works aggressively to extend bridge life by performing preventive maintenance on a routine basis.

Consistent with federal requirements, MnDOT performs a detailed inspection on each of its bridges on a periodic basis (usually at two-year intervals, some more or less frequently based on inspection results, as outlined in the MnDOT Bridge and Structure Inspection Program Manual). MnDOT's bridge office is required to house inventory, inspection and condition data on all bridges in the state regardless of ownership, and includes all for federal reporting. Regular communication and audit of statewide inspection data is performed by MnDOT.

Preventive maintenance activities – flushing, crack sealing, joint maintenance, spot painting, and other minor repairs – are typically performed by internal staff either in accordance with a recommended frequency or as needed, based on the element condition documented within Structure Information Management System. Most bridges are flushed annually, or as often as constraints allow, 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). Constraints from following treatment strategies include staffing, funding, work zone traffic control limitations on high-volume bridges (typically on Interstate Highways), and other system priorities. Crack sealing on bridge decks and barrier and poured joint sealing are typically performed on a five year frequency. Other preventive maintenance activities, such as expansion joint maintenance, as well as reactive maintenance activities, such as patching, are performed in response to conditions noted in the inspection reports and tracked in SIMS.

MnDOT has developed a strong preventive maintenance culture within its bridge engineering and bridge maintenance groups. Each year, all new employees (and some in the existing workforce) receive thorough training in bridge preservation covering needs, benefits, philosophy, causes and problems related to specific deterioration types, numerous treatment techniques (from deck flushing to full depth joint replacement), appropriate preventive maintenance intervals, and tracking and recording expectations.

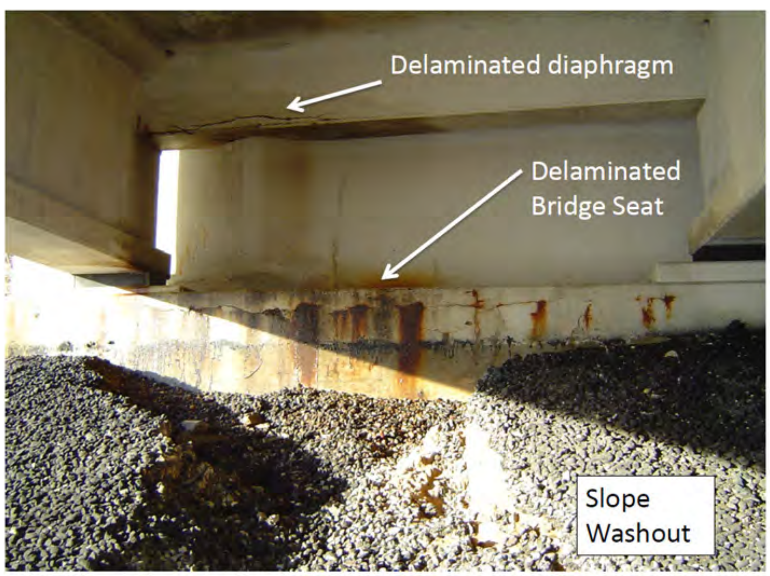
Bridges and culverts deteriorate over time. Steel beams, and reinforcing steel in particular, are prone to corrosion. Paint and concrete cover the steel and protect it from corrosion. But paint and concrete are often exposed to weather, traffic, erosion, animals, chemicals and collisions, and therefore require preventive as well as reactive care. These materials can also crack as they age, thus allowing corrosive water and chemicals to penetrate the materials, worsening deterioration. MnDOT uses information from its SIMS and inspection programs to forecast needs and track work performed.

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. Leaking expansion joints can lead to increased deterioration of underlying elements due to greater exposure to deicing chemicals. MnDOT uses internal staff to replace glands and otherwise perform preventive joint maintenance to minimize damage caused by leaks at joints (Figure 6-11).

Bridge culverts tend to be more durable, and require very little maintenance because they are generally protected underground. Most are precast, therefore they are manufactured under more controlled conditions. They also deteriorate, but at a slower rate than bridges.

To estimate the cost effectiveness of management strategies (minimum maintenance compared to MnDOT's more optimized typical preventive maintenance practices), MnDOT performed a network level life cycle cost analysis using a Markov modeling approach (Figures 6-12 through 6-15). The analysis uses bridge condition data to project deterioration rates and quantify the number of bridges typically addressed per year within the various condition

Figure 6-11: Effects of Leaking Deck Joints



states. Expert judgment was used to estimate the numbers and health improvement effects of various treatments. Actual unit cost data from MnDOT financial systems was used to price treatments, which in conjunction with the department's adopted discount rate, yields a theoretical equivalent uniform annual cost for a bridge of average size.

KEY TAKEAWAYS

The analysis suggests that EUAC can be reduced from approximately $56,000 for the minimum maintenance strategy to $36,000 for a strategy including more aggressive preventive maintenance.

MnDOT's typical preventive maintenance strategies are believed to extend the average service life of each structure from about 50 to 80 years and save considerable sums compared to a minimum maintenance-only strategy.

In keeping with this TAMP's goals of providing more actionable guidance to MnDOT's Bridge maintenance community, the Bridge Office has begun to explore additional cost modeling techniques in addition to the Markov modeling approach (see Chapter 9). This work will be pursued during the next TAMP update cycle.

Figure 6-12: Life Cycle Management Strategy for Bridge Decks

STRATEGY	TREATMENT	INTERVAL (YEARS)	$/BRIDGE	% TREATED ANNUALLY IN GOOD CONDITION	% TREATED ANNUALLY IN SATISFACTORY CONDITION	% TREATED ANNUALLY IN FAIR CONDITION	% TREATED ANNUALLY IN POOR CONDITION
Preventive Maintenance	Joint sealing	5	$1,529	20%	20%	20%	N/A
Preventive Maintenance	Deck sealing	5	$37,406	20%	20%	20%	N/A
Preventive Maintenance	Crack sealing	5	$1,500	20%	20%	20%	N/A
Preventive Action	Joint repair (patch)	Condition-based	$38,215	N/A	1%	2%	N/A
Reactive Maintenance	Deck repair	Condition-based	$16,833	N/A	2%	35%	15%
Major Preservation	Overlay	Condition-based	$130,921	N/A	N/A	5%	2%
Reactive Maintenance	Rail repair/ replace	Condition-based	$127,705	N/A	1%	5%	N/A
Rehab and Replacement	Redeck	Condition-based	$1,122,184	N/A	N/A	N/A	5%

Figure 6-13: Life Cycle Management Strategy for Bridge Superstructures

STRATEGY	TREATMENT	INTERVAL (YEARS)	$/BRIDGE	% TREATED ANNUALLY IN GOOD CONDITION	% TREATED ANNUALLY IN SATISFACTORY CONDITION	% TREATED ANNUALLY IN FAIR CONDITION	% TREATED ANNUALLY IN POOR CONDITION
Routine Maintenance	Inspection	1-2	$1,111	60%	60%	60%	60%
Preventive Maintenance	Flushing	Annual	$500	75%	75%	75%	75%
Preventive Maintenance	Lube bearings	4	$26,600	0.1%	0.2%	N/A	N/A
Preventive Maintenance	Spot painting	5	$19,500	N/A	2%	5%	N/A
Major Preservation	Full painting	Condition-based	$377,480	N/A	3%	5%	N/A
Reactive Maintenance	Patching	Condition-based	$30,000	N/A	1%	3%	5%
Reactive Maintenance	Repair/replace bearings	Condition-based	$46,549	N/A	N/A	N/A	5%
Reactive Maintenance	Repair steel	Condition-based	$50,000	N/A	N/A	2%	5%
Rehab and Replacement	Replace elements	Condition-based	$100,000	N/A	N/A	N/A	1%
Rehab and Replacement	Replace structure	Condition-based	$2,702,941	N/A	N/A	N/A	20%

Figure 6-14: Life Cycle Management Strategy for Bridge Substructures

STRATEGY	TREATMENT	INTERVAL (YEARS)	$/BRIDGE	% TREATED ANNUALLY IN GOOD CONDITION	% TREATED ANNUALLY IN SATISFACTORY CONDITION	% TREATED ANNUALLY IN FAIR CONDITION	% TREATED ANNUALLY IN POOR CONDITION
Reactive Maintenance	Patching	Condition-based	$56,070	N/A	N/A	10%	15%
Reactive Maintenance	Slope paving repair	Condition-based	$26,166	N/A	1%	1%	N/A
Reactive Maintenance	Erosion/scour repair	Condition-based	$25,000	N/A	N/A	5%	5%
Rehab and Replacement	Replace elements	Condition-based	$100,000	N/A	N/A	N/A	1%

Figure 6-15: Life Cycle Management Strategy for Bridge Culverts (>10ft)

STRATEGY	TREATMENT	INTERVAL (YEARS)	$/BRIDGE	% TREATED ANNUALLY IN GOOD CONDITION	% TREATED ANNUALLY IN SATISFACTORY CONDITION	% TREATED ANNUALLY IN FAIR CONDITION	% TREATED ANNUALLY IN POOR CONDITION
Preventive Maintenance	Inspection	1-4	$1,111	60%	60%	60%	60%
Reactive Maintenance	Patching	Condition-based	$12,104	N/A	N/A	5%	10%
Rehab and Replacement	Replacement	Condition-based	$250,000	N/A	N/A	N/A	25%

OTHER ASSETS LIFE CYCLE PLANNING

Highway Culverts

Culverts are inspected on an interval 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. MnDOT maintains and annually reports on a performance measure for the conduct of inspections. MnDOT also maintains a culvert inventory including inspection records and condition information in TAMS. The department has developed treatment decision trees based on culvert sizes, types, condition, and several other "flags" which aid significantly in the life cycle planning (capital investment, as well as maintenance) of the system of culverts.

Other drainage system components have different inspection frequencies. Federal MS4 permits require storm water ponds to be inspected once every five years, while structural pollution control devices are inspected every year and infiltration/filtration basins the first two years after construction and then every two years thereafter. Culverts are flushed to remove accumulated debris, when sedimentation is restrictive to flow or when culverts are video-inspected, 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 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 voids. The presence of these pockets tends to accelerate deterioration and can potentially cause a local collapse of the roadway above.

LIFE CYCLE PLANNING SCENARIOS

The highway culverts life cycle analysis included two scenarios shown in Figure 6-16. The minimum maintenance scenario included only routine maintenance, with the maintenance costs being estimated using data from TAMS. Current practice scenario added three corrective actions including joint repair, pave invert, and replace ends.

KEY TAKEAWAYS

Condition inspections in accordance with MnDOT's adopted cycle are a primary means of mitigating risk of drainage infrastructure failure. Inspection frequency is based on condition and inspection findings are important as they drive routine maintenance. These corrective actions were anticipated to reduce the equivalent annual cost per culvert from $507 to $356 on a network-wide average culvert basis. Treatment decision trees have been developed based on culvert size, type, condition, and other "flags" which aid in life cycle planning.

Figure 6-16: Highway Culverts Life Cycle Planning Scenarios

ACTIVITY	TREATMENT WORK TYPE	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICE
Inspection	Routine Maintenance	$70	Applied	Applied
Cleaning	Routine Maintenance	$380	Applied	Applied
Reset Ends	Routine Maintenance	$3,000	Applied	Applied
Joint Repair	Corrective Actions	$3,300	Not Applied	Applied
Pave Invert	Corrective Actions	$1,980	Not Applied	Applied
Replace Ends	Corrective Actions	$5,800	Not Applied	Applied
Slipliner	Rehabilitation or Replacement	$12,000	Applied	Applied
Cured Inplace Liner	Rehabilitation or Replacement	$25,000	Applied	Applied
Trench Replacement	Rehabilitation or Replacement	$38,000	Applied	Applied
Jack Replacement	Rehabilitation or Replacement	$71,000	Applied	Applied
MNDOT EUAC PER CULVERT	N/A	N/A	$507	$356

Deep Stormwater Tunnels

MnDOT, in partnership with the city of Minneapolis, maintains an inventory of eight deep stormwater tunnels that range in length from 0.2 to 4.6 miles, which adds up to 73,392 linear feet or nearly 14 total miles. All eight tunnels have had detailed inspection studies completed, which identify specific conditions and repairs. Minneapolis also performs a visual walk-through inspection of tunnels every two to five years. Typical maintenance consists of repairing cracks and drilling and grout filling the annular space between the outside of the concrete liner and the eroded sandstone native soil.

During the preparation of MnDOT's pilot TAMP, generalized risks for these deep stormwater tunnels were assessed, life cycle cost assessments were prepared, and priority strategies were developed for mitigating undermanaged risks. Since the pilot TAMP was prepared, MnDOT has made substantial investments in preventive maintenance (grouting the annular space of the Interstate 35W tunnel), and followed through on its priority of using the bridge management software to manage these tunnels. Due to the small sample size, high-level assumptions needed, unique considerations of the remaining individual tunnels, and limited alternatives, MnDOT did not perform a generic life cycle cost assessment for these stormwater tunnels in this TAMP. It will perform analyses as needed to make future management and investment decisions.

Overhead Sign Structures

A less-formalized element-level inspection process and rating system is used for overhead sign structures in Greater Minnesota districts. As a result of this TAMP process, MnDOT has developed a uniform statewide overhead sign structure inspection form and is working on a corresponding inspection process rating system. Sign structure inspection is newly implemented.

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. Most of the responsibility for inspecting and maintaining these structures falls on MnDOT district staff, and MnDOT has developed cost recording protocols to improve the cost data for these assets.

LIFE CYCLE PLANNING SCENARIOS

The overhead sign structures life cycle analysis included four scenarios shown in Figure 6-17. The minimum maintenance scenario included only reactive maintenance, with the maintenance costs being estimated using data from TAMS. Current practice scenario, under Scenario B, added two inspection activities -- structure and out of cycle inspections -- as well as tightening nuts and a major rehabilitation one time during the sign structure's life. Scenario C increases the frequency of nut tightening to every five years. For existing signs in the field, tightening the nuts more frequently may extend the life of the sign but may cost more per structure. In Scenario D, MnDOT would work to ensure proper initial installation of overhead signs.

Figure 6-17: Overhead Sign Structures Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICE	STRATEGY C PREVENTIVE MAINTENANCE	STRATEGY D PROPER INITIAL INSTALLATION
Reactive Maintenance	$100	Annual	Annual	Annual	Annual
Structural Inspection	$250	None	Every 5 years	Every 5 years	Every 5 years
Out of Cycle Inspection	$26	None	Annual	Annual	Annual
Tighten Nuts	$257	None	One Time	Every 5 years	None
Major Rehabilitation	$6,250	None	At 30 years	At 30 years	At 30 years
EXPECTED LIFE	N/A	40 YEARS	40 YEARS	41-50 YEARS	41-50 YEARS
MNDOT EUAC PER STRUCTURE	N/A	$570	$713	$243-$867	$209-$649

KEY TAKEAWAYS

If signs did not need nut tightening over the life of the sign structure, MnDOT could save considerably versus its current practice scenario. A current MnDOT research project will provide national guidance on nut tightening issues. Conducting inspections according to the cycle adopted is an important part of minimizing risk related to these structures.

High-Mast Tower Light Structures

Statewide high-mast light tower structures are inspected on a five-year cycle due to MnDOT's recently formalized inspection program; a similar program with element level inspections exists for overhead sign structures.

Similar to pavements and bridges, which are managed through a fairly mature process, protocols for inspection, and management of high-mast light tower structures have been on a regularly defined program for a couple decades. However, over the last couple of years, MnDOT has invested significant resources to improve the way these assets are managed and the condition of the assets.

Typical maintenance actions performed on high-mast light tower structures include tightening and levelling of nuts, removing debris, and replacing components that are not functioning adequately. Most of the responsibility for inspecting and maintaining these structures falls on MnDOT district staff, and MnDOT has developed cost-recording protocols to improve the cost data for these assets.

LIFE CYCLE PLANNING SCENARIOS

The high mast tower light life cycle analysis included three scenarios shown in Figure 6-18. The minimum maintenance scenario included only reactive maintenance, with the maintenance costs being estimated using data from TAMS. Scenario B added a periodic structural inspection as well as an out of cycle structural inspection, nut tightening, and replacing the LED luminaires on a periodic basis. These added tasks were anticipated to reduce the cost of reactive maintenance by 5 percent and extend the expected life from 40 years to 50 years. Scenario C added periodic exercising of the lowering mechanism, which was anticipated to reduce the cost of reactive maintenance by an additional 5 percent.

KEY TAKEAWAYS

The analysis indicated that Scenario B, which included inspections, nut tightening and LED replacement had the lowest equivalent uniform annualized cost. The exercising of the lowering mechanism in the highest scenario cost more than it saved, although it was still better than the lowest effort scenario.

Figure 6-18: High Mast Tower Light Structures Life Cycle Planning

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICE	STRATEGY C PREVENTIVE MAINTENANCE
Reactive Maintenance	$3,017	Every 5 years	Every 5 years	Every 5 years
Structural Inspection	$132	None	Every 5 years	Every 5 years
Tighten Nuts	$250	None	Every 50 years	Every 50 years
Out of Cycle Inspection	$132	None	Every 50 years	Every 50 years
Replace LED Luminaires	$4,000	None	Every 15 years	Every 15 years
Exercise Lowering Mechanism	$78	None	None	Annual
EXPECTED LIFE	N/A	40 YEARS	50 YEARS	50 YEARS
MNDOT EUAC PER STRUCTURE	N/A	$1,812	$1,774	$1,803

Noise Walls

Noise walls are inspected on a 10-year cycle with the last inventory and inspection completed in 2012. MnDOT completes out of cycle inspections if a serious defect is found that requires more frequent monitoring.

Typical reactive maintenance activities are performed on an annual basis. Minor rehabilitation activities include minor concrete panel repair or wood re-planking. Most of the responsibility for inspecting and maintaining noise walls falls on MnDOT district staff especially Metro District staff. Metro District has 95 percent of all noise walls statewide.

LIFE CYCLE PLANNING SCENARIOS

The concrete noise wall life cycle analysis included three scenarios in Figure 6-19. The minimum maintenance scenario included only reactive maintenance, with the maintenance costs being estimated using data from TAMS. Scenario B added structural inspections every 10 years. Scenario B also added a minor rehabilitation every 27 years. This scenario was anticipated to add up to 20 years on the expected life of the wall. Scenario C additionally added splash zone sealing every five years, which was anticipated to increase the expected life of the wall from 80 years to 95-120 years.

The wood panel noise wall life cycle analysis included three scenarios in Figure 6-20. The minimum maintenance scenario included only reactive maintenance, with the maintenance costs being estimated using data from TAMS. Scenario B added structural inspections every 10 years with out of cycle inspections as needed. Noise walls required out of cycle inspections if a serious defect is found that requires more frequent monitoring. Scenario B also added re-planking every 30 years. This scenario was anticipated to add up to 20 years on the expected life of the wall. Scenario C additionally added splash zone sealing every 5 years which was anticipated to increase the expected life of the wall from 60 years to 75-100 years.

Figure 6-19: Concrete Noise Walls Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICE	STRATEGY C PREVENTIVE MAINTENANCE
Reactive Maintenance	$838	Annual	Annual	Annual
Structural Inspection	$455	None	Every 10 years	Every 10 years
Out of Cycle Inspection	$23	None	Annual	Annual
Minor Rehabilitation	$54,355	None	Every 27 years	Every 27 years
Splash Zone Sealing	$16,000	None	None	Every 5 years
EXPECTED LIFE	N/A	80 YEARS	81-100 YEARS	95-120 YEARS
MNDOT EUAC PER NOISE WALL	N/A	$2,749	$2,137-$3,359	$2,818-$3,968

Figure 6-20: Wood Panel Noise Walls Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICE	STRATEGY C PREVENTIVE MAINTENANCE
Reactive Maintenance	$1,292	Annual	Annual	Annual
Structural Inspection	$570	None	Every 10 years	Every 10 years
Out of Cycle Inspection	$29	None	Annual	Annual
Re-planking	$18,424	None	Every 30 years	Every 30 years
Splash Zone Sealing	$8,520	None	None	Every 5 years
EXPECTED LIFE	N/A	60 YEARS	61-80 YEARS	75-100 YEARS
MNDOT EUAC PER NOISE WALL	N/A	$4,251	$2,404-$4,348	$1,874-$3,687

KEY TAKEAWAYS

Current practice appears to have the lowest life cycle cost for concrete noise walls while adding splash zone sealing could lower the life cycle costs for wood panel noise walls. Using activities such as re-planking and splash zone sealing will extend the life of the asset but not certain for how long. Splash zone sealing of concrete walls did not equate to cost savings even if life of the wall was extended by 20 years. Concrete noise walls are a lower cost range alternative in the minimum maintenance and current practice strategies over wood panel walls.

There were a few limitations to this life cycle analysis. For this analysis, risk is not incorporated as a monetary value. Risk impacts should be included in conjunction with life cycle analysis strategies. For example, performing structure inspections may only increase life-cycle costs $100/structure but will lower the risk of structure collapse. In addition, noise wall life cycle planning should also consider noise abatement and aesthetics that are not included here. More research is also needed on how preventive maintenance activities increase life.

Signals

MnDOT conducts annual operation checks on traffic signals. This includes checking signal timing, a cursory review of intersection hardware, replacing the cabinet filter, and removing any debris. Every two years, MnDOT inspects the electronics of the signal cabinet including testing the malfunction monitor unit. Every three years, MnDOT completes an in-depth electrical inspection of the wiring and hardware.

Minor rehabilitation activities performed include replacing LED indications and replacing the electronics. Most of the responsibility for inspecting and maintaining these structures falls on MnDOT Electrical Services and district staff.

LIFE CYCLE PLANNING SCENARIOS

The traffic signal life cycle analysis included four strategies shown in Figure 6-21. The lowest effort strategy, Strategy A, included only reactive maintenance, with the maintenance costs estimated using data from TAMS. Strategy B consisted of three periodic inspections/preventive maintenance tasks -- one each for operational, electrical, and electronic. These inspection/ preventive maintenance and replacement tasks were anticipated to reduce reactive maintenance costs by 5 percent. Strategy C consisted of replacing the electronics and the LED indications proactively on a periodic basis. Strategy D consisted of periodic structural inspection, which was anticipated to increase the expected life of the entire signal system from 30 years to 40 years.

Figure 6-21: Signals Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A REACTIVE MAINTENANCE	STRATEGY B PREVENTIVE MAINTENANCE	STRATEGY C EQUIPMENT REPLACEMENTS	STRATEGY D STRUCTURAL INSPECTION
Reactive Maintenance	$399	Annual	Annual	Annual	Annual
Operations Check	$74	None	Annual	None	None
Electrician Preventive Maintenance	$124	None	Every 3 years	None	None
Electronic Preventive Maintenance	$132	None	Every 2 years	None	None
Replace LED Indications	$20,000	None	None	Every 10 years	None
Replace Electronics	$30,000	None	None	Every 15 years	None
Structural Inspection	$1,000	None	None	None	Every 5 years
EXPECTED LIFE	N/A	30 YEARS	30 YEARS	30 YEARS	40 YEARS
MNDOT EUAC PER SIGNAL	N/A	$8,885	ADD $23	ADD $1,908	SUB $1,523

KEY TAKEAWAYS

The analysis indicated that the added inspections/preventive maintenance tasks cost more than they saved. Even if the inspections/preventive maintenance and replacement tasks had eliminated all reactive maintenance costs, it would still cost more than it saved. While the inspections/preventive maintenance tasks of the middle scenario did not demonstrate benefit from a life cycle cost point of view, MnDOT considers these efforts beneficial for operational and liability reasons. Proactively replacing the LED indications and electronics also cost more than it saved. Conducting structural inspections lowered the equivalent uniform annual cost, saving more than it cost, by lengthening the time between total re-builds of the signal system.

Lighting

MnDOT conducts electrical inspections every five years. MnDOT does not currently have a consistent inspection schedule for inspecting lighting structures. Minor rehabilitation activities performed include replacing LED indications and replacing the electronics. Most of the responsibility for inspecting and maintaining these structures falls on MnDOT Electrical Services and district staff.

LIFE CYCLE PLANNING SCENARIOS

The roadway lighting life cycle analysis included three scenarios shown in Figure 6-22. The minimum maintenance scenario included only reactive maintenance and re-setting knocked down poles, with the maintenance costs being estimated using data from TAMS. Scenario B added a periodic electrical inspection as well as replacing the LED luminaires on a periodic basis. The electrical inspection was anticipated to reduce the frequency of reactive maintenance from once every four-years to once every five-years on average per pole. Scenario C added periodic structural inspection, which was anticipated to increase the expected life of the light pole from 30 years to 40 years.

KEY TAKEAWAYS

The analysis indicated that Scenario C, which included electrical inspection and structural inspection, had the lowest equivalent uniform annualized cost, mostly due to lengthening the time between complete replacement of the light poles. The added inspections and LED replacements in the middle scenario cost more than they saved, making it the highest cost scenario. The lowest effort scenario that included no inspection or LED replacements had costs between the other scenarios. While the inspections and LED replacements of the middle scenario were not beneficial from a life cycle cost point of view, MnDOT considers these efforts beneficial to maintain the safety impacts of the lighting.

Figure 6-22: Lighting Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICES	STRATEGY C STRUCTURAL INSPECTION
Knockdowns	$1,978	Every 5 years	Every 5 years	Every 5 years
Reactive Maintenance	$1,841	Every 4 years	Every 5 years	Every 5 years
Electrical Inspection	$55	None	Every 5 years	Every 5 years
Replace LED Indications	$500	None	Every 15 years	Every 15 years
Structural Inspection	$140	None	None	Every 5 years
EXPECTED LIFE	N/A	30 YEARS	30 YEARS	40 YEARS
MNDOT EUAC PER STRUCTURE	N/A	$307	$317	$295

Pedestrian Infrastructure

Responsibility for inspections and maintenance varies on sidewalks and ramps along state highways. In some cases, MnDOT has agreements with the local government to inspect and maintain pedestrian infrastructure. Frequency of local inspections can vary but are generally completed every five years. MnDOT schedules inspections every 10 years with the last full inspection completed in 2013.

Minor rehabilitation activities generally address any heaving or height differences between adjacent concrete slabs removing the hazard. This includes grinding the slab, slabjacking (raising a sunken slab), or removing vegetation that may be causing the slab to become uneven. These rehabilitation treatments are more commonly used on sidewalks than curb ramps.

Figure 6-23: Curb Ramps Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICES	STRATEGY C STRUCTURAL INSPECTION
Structural Inspection	$100	None	Every 10 years	Every 10 years
Grinding/Slabjacking/ Vegetation removal	$250	None	None	Every 5 years
EXPECTED LIFE	N/A	20 YEARS	20 YEARS	21-35 YEARS
MNDOT EUAC PER RAMP	N/A	$228	$232	$41-233

LIFE CYCLE PLANNING SCENARIOS

The pedestrian infrastructure life cycle analysis included three scenarios shown in Figure 6-23 for curb ramps. The minimum maintenance scenario included only reactive maintenance, with the maintenance costs estimated using data from TAMS. Scenario B added structural inspection every 10 years to match MnDOT's current practice. Scenario C added a rehabilitation treatment including grinding, slabjacking or vegetation removal every five years, which was anticipated to increase the expected life of the curb ramp by up to 15 years.

The pedestrian infrastructure life cycle analysis included three scenarios shown in Figure 6-24 per sidewalk (300 ft. block). The minimum maintenance scenario included only reactive maintenance, with the maintenance costs estimated using data from TAMS. Scenario B added structural inspection every 10 years to match MnDOT's current practice. It also added a rehabilitation treatment including grinding, slabjacking or vegetation removal. Scenario C added a panel replacement every 10 years, which was anticipated to increase the expected life of the sidewalk by up to 20 years.

Figure 6-24: Sidewalk Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICES	STRATEGY C STRUCTURAL INSPECTION
Inspection	$100	None	Every 10 years	Every 10 years
Grinding/ Slabjacking/ Vegetation removal	$250	None	Every 20 years	Every 20 years
Panel Replacements	$200	None	None	Every 10 years
EXPECTED LIFE	N/A	40 YEARS	40 YEARS	41-60 YEARS
MNDOT EUAC PER SIDEWALK	N/A	$183	$269	$133-293

KEY TAKEAWAYS

Structural inspection and maintenance will increase the life of the pedestrian infrastructure, reduce risk, and lower annual costs for pedestrian ramps. If sidewalk life increases 10+ years then the annual cost of Scenario 3 is lowest. Pedestrian infrastructure life cycle planning includes compliance as well as structural condition information. ADA compliance includes non-condition items such as obstructions or non-compliant slopes.

Buildings

MnDOT's Building Services section completed an inspection of all buildings in 2014. By statute all agencies with real property are required to report to the Department of Administration the condition of their buildings every year on September 1. Every facility and the systems that make-up the facility are inspected once every three years. The inspections are conducted by one or two MnDOT staff from each district and take about 40 hours for each staff member.

LIFE CYCLE PLANNING SCENARIOS

Figures 6-225 through 6-40 show the treatment strategies for each building system, rather than for a "typical" building, since building types vary.

Figure 6-25: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station/Small Truck Storage Facility/Salt Shelters - Foundation/Slabs/Exterior Walls/Roof Structure

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Preventive maintenance (Walls)	Sq. Ft	$0.90
Installation	Preventive Maintenance (Slabs)	Sq. Ft	$1.75
Poor to Very Poor	Minor Rehabilitation (Walls)	Sq. Ft	$8.50
As Needed	Minor Rehabilitation (Slabs)	Sq. Ft	$7
As Needed	Replacement (Walls)	Sq. Ft of Bldg. Gross Sq. Footage	$19.75

Figure 6-26: Typical Life Cycle Management Strategy for Treatments and Costs for Heated Equipment Storage/Unheated Equipment Storage/Brine Facility - Foundation/Slabs/Exterior Walls/Roof Structure

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Preventive maintenance (Metal Panel Walls)	Labor Hrs.	8
Installation	Preventive maintenance (Slabs)	Sq. Ft	$1.75
As Needed	Replacement (Metal Panel Walls)	Sq. Ft	$16

Figure 6-27: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station/Small Truck Storage Facility/Heated Equipment Storage/Unheated Equipment Storage/Brine Facility - Exterior Doors and Windows

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Good to Poor	Routine/Preventive maintenance	Door or Window	$35
Poor to Very Poor	Minor Rehabilitation	Door or Window	$350
Very Poor	Full Replacement	Sq. Ft of Bldg. Gross Sq. Footage	$5

Figure 6-28: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station/Small Truck Storage Facility - Roofing

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Routine Maintenance	Total	$225
Very Poor (25 years)	Full Replacement	Sq. Ft	$12

Figure 6-29: Typical Life Cycle Management Strategy for Treatments and Costs for Heated Equipment Storage/Unheated Equipment Storage/Brine Facility - Roofing

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Replacement (Metal Roof)	Sq. Ft	$16

Figure 6-30: Typical Life Cycle Management Strategy for Treatments and Costs for Salt Shelters - Roofing

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Yearly	Routine Maintenance	Labor Hrs.	$16
Very Poor (25 years)	Replacement (Fabric)	Sq. Ft	$12

Figure 6-31: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station/Small Truck Storage Facility - Interior Finishes

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Good to Fair	Routine Maintenance (Carpet)	Sq. Ft	$0.30
Not Typically Done	Routine Maintenance (Wall Finishes)	Sq. Ft	$0.67
20-25 Years/Poor to Very Poor	Replacement (Carpet)	Sq. Ft	$5.75
20-25 Years/Poor to Very Poor	Replacement (Wall Finishes)	Sq. Ft	$2.75
20-25 Years/Poor to Very Poor	Replacement (Ceiling Tiles)	Sq. Ft	$8.88

Figure 6-32: Typical Life Cycle Management Strategy for Treatments and Costs for Brine Facility - Interior Finishes

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Routine Maintenance (Wall Finishes)	Labor Hrs.	8
20-25 Years/Poor to Very Poor	Replacement (Wall Finishes)	Sq. Ft	$2.75

Figure 6-33: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility - HVAC Systems

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Ongoing	Preventive maintenance	Sq. Ft per Year	$0.65
10-30 Years	Minor Rehabilitation	Sq. Ft per 15 Years	$1.50
Poor	Replacement (Boiler + Chiller)	Sq. Ft	$5.50

Figure 6-34: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station - Electrical and Lighting

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Routine Maintenance	Labor Hrs. (MnDOT)	$0
As Required (40 year life expectancy)	Replacement (Switchgear/Sub-Panels)	Sq. Ft	$16
As Needed	Replacement (Light Fixtures)	Sq. Ft	$5.25

Figure 6-35: Typical Life Cycle Management Strategy for Treatments and Costs for Heated Equipment Storage/Unheated Equipment Storage/Brine Facility - Electrical and Lighting

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Routine Maintenance	Labor Hrs. (MnDOT)	$0
As Required (40 year life expectancy)	Full Replacement	Sq. Ft	$14.50

Figure 6-36: Typical Life Cycle Management Strategy for Treatments and Costs for Salt Shelter - Electrical and Lighting

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Routine Maintenance	Labor Hrs. (MnDOT)	$0
As Required	Full Replacement	Sq. Ft	$14.50

Figure 6-37: Typical Life Cycle Management Strategy for Treatments and Costs for Small Truck Storage Facility - Electrical and Lighting

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Not Typically Done	Routine Maintenance	Labor Hrs. (MnDOT)	$0
As Required (40 year life expectancy)	Replacement	Sq. Ft	$21.25

Figure 6-38: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station/Small Truck Storage Facility/Brine Facility - Plumbing and Fixtures

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
As Needed (40+ year life expectancy)	Replacement (Piping + Fixtures)	Sq. Ft	$14.25
Poor (15 year life expectancy)	Replacement (Water Heaters) (Does Not Apply to Brine Facilities)	Sq. Ft	$0.07

Figure 6-39: Typical Life Cycle Management Strategy for Treatments and Costs for Large Warehouse/Office Facility/Rest Area/Weigh Station/Small Truck Storage Facility - Communication, Security, and Fire Alarm Systems

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
15-20 years	Replacement (Fire Alarm)	Sq. Ft	$5.60
15-20 years	Replacement (Electronic Lock System)*Only Large Warehouse/ Office Facility/Weigh Station	Sq. Ft	$1.90
15-20 years	Replacement (Communications)	Sq. Ft	$1.90

Figure 6-40: Typical Life Cycle Management Strategy for Treatments and Costs for Weigh Station - Scale Mechanisms

TYPICAL AGE (YEARS) OR CONDITION LEVEL WHEN TREATMENT IS APPLIED	TREATMENT	UNIT	COST/ UNIT
Poor	Replacement	Scale Mechanism	$120,250

KEY TAKEAWAYS

Due to the complexities of having several systems with differing expected lives per building type, life cycle cost analyses were not performed. In achieving optimal life cycle planning for buildings, it is important to perform timely preventive maintenance and replacement activities in order to extend the life of certain individual building systems (e.g., doors and windows).

ITS Infrastructure

There are 14 different ITS infrastructure assets included in TAMP. Each asset has different life cycles, inspection frequencies and maintenance activities. For example, dynamic message signs are inspected annually. This includes checking the fan, pixel board, power supply, as well as checking for animal infestations, leaks and debris.

Rehabilitation activities include fan replacement, pixel board replacement and power supply replacement. Most of the responsibility for inspecting and maintaining ITS assets falls on MnDOT district staff, especially for Metro District, which has a majority of all ITS assets statewide.

LIFE CYCLE PLANNING SCENARIOS

A life cycle analysis was completed on dynamic message signs as an example of ITS infrastructure in Figure 6-41. The dynamic message signs life cycle analysis included two scenarios. The minimum maintenance scenario does not include any preventive or reactive maintenance. Scenario B added a scheduled fan replacement every four years, pixel board replacement every 10 years, and power supply replacement every 13 years. This scenario was anticipated to increase the expected life of dynamic messages signs from six years to 15 years.

KEY TAKEAWAYS

Scenario B was anticipated to increase the expected life of dynamic messages signs from six years to 15 years. In addition, the annual cost per sign decreased from $8,493 to $286. This is primarily due to having the sign last over twice as long with inspections and rehabilitation treatments. A risk not incorporated into this analysis is that of technology changing. Life cycle planning for ITS assets can prove be difficult due to technology changes and how new technologies may change life cycles.

Figure 6-41: Dynamic Message Signs Life Cycle Planning Scenarios

TREATMENTS	TYPICAL COSTS	STRATEGY A MINIMUM MAINTENANCE	STRATEGY B CURRENT PRACTICES
Filter Change	$250	None	Annual
Fan Replacement	$250	None	Every 4 years
Pixel Board Replacement	$250	None	Every 10 years
Power Supply Replacement	$250	None	Every 13 years
EXPECTED LIFE	N/A	6 YEARS	15 YEARS
MNDOT EUAC PER SIGN	N/A	$8,493	$286

Summary of Life Cycle Cost Estimates

The information presented in the previous analyses provides insight into MnDOT's desired preservation practices and illustrates how much it costs per year to maintain an asset when costs are presented in an Equivalent Uniform Annual Cost or "today's dollars" format. The information shows that timely preservation work is very effective in reducing life cycle costs for pavements, bridges and other assets, primarily by extending the service life of these assets. Currently, MnDOT does not have fully implemented tools, nor sufficiently nuanced historical and forecasting data, to optimize all preservation practices objectively. However, numerous improvements have been made across all asset classes referenced as a result of increased focus since preparation of the pilot TAMP. As a result, greater cost savings could be achieved through fine-tuning the timing and application of preservation actions given continually improving deterioration and treatment effectiveness data. MnDOT does believe that its culture embraces and applies asset management principles at a relatively high level, nonetheless.

Improving Life Cycle Management

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 programming decisions. Combined with the ability to generate policy and program alternatives, this approach enables better-informed decision-making. See Figure 6-42 for a cross-asset comparison of annualized life cycle costs.

Figure 6-42: Annualized Life Cycle Cost Estimates by Asset

ASSET CLASS	ANNUALIZED COST RANGE
Pavements (flexible)	$12,000 - $12,560 per lane-mile
Pavements (rigid)	$18,940 - $21,170 per lane-mile
Bridges	$36,000 - $56,000 per bridge
Highway Culverts	$356 - $507 per small culvert
Overhead Sign Structures	$209 - $867 per structure
High-Mast Light Tower Structures	$1,774 - $1,812 per structure
Noise Walls (concrete)	$2,137 - $3,968 per structure
Noise Walls (wood panel)	$1,874 - $4,348 per structure
Signals	$7,362 - $10,816 per signal
Lighting Poles	$295 - $317 per structure
Pedestrian Infrastructure (curb ramp)	$41 - $233 per ramp
Pedestrian Infrastructure (sidewalk)	$133 - $293 per sidewalk (300 ft block)
Buildings	Not calculated
ITS (dynamic message signs)	$286 - $8,493 per sign

MnDOT has a culture of embracing continuous improvement. As evidence, note that a high number of improvements identified in the pilot TAMP have been completed at this time as shown in Chapter 9: Implementation and Future Developments. MnDOT also invited an FHWA contractor to perform an asset management gap assessment, and is implementing the recommendations of that effort. MnDOT will continue to identify and pursue solutions to more nuanced issues as it nears its goals of comprehensive and holistic asset life cycle management.

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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 many state-owned assets, condition is used to identify performance gaps, defined here as the difference between projected performance and the performance target. This chapter presents condition results alongside state and federal targets.

TARGETS APPEARING IN THE TAMP

The TAMP includes a mix of state targets and required federal targets. The state targets were established as part of the pilot TAMP for pavements, bridges, culverts, deep stormwater tunnels, and overhead sign structures. Targets for other assets were established in subsequent planning processes. MnDOT work groups developed asset-specific target methodologies based on existing and anticipated future conditions, current information on capital and maintenance investments, and anticipated deterioration and risk. For example, the hydraulic work group identified the number of culverts in poor and very poor condition and determined how many of them deteriorate to a worse condition annually. They 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.

Chapter 2 described the MnSHIP development process, looking at trade-offs between investment levels, performance levels, and risks to evaluate and select investment priorities. Chapter 3 described the federal and state targets.

The approved 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.

Federal Targets and Gaps

As mentioned in Chapter 3, MnDOT is required to report on federal performance measures and targets for bridge and pavement on the NHS. The TAMP must also show the gaps between expected performance and the federal targets. Figure 7-1 below shows MnDOT's adopted federal performance targets and existing condition for bridges and pavements. Since these targets are short-term and fall within the existing four-year STIP, MnDOT set targets that it can achieve given existing programmed projects. Because of this, there are no anticipated funding gaps to meet the federal targets.

Figure 7-1: Federal Performance Measures and Targets

ASSET	PERFORMANCE MEASURE	EXPLANATION	CURRENT CONDITION (2017)	2-YEAR FEDERAL TARGET (2020)	4-YEAR FEDERAL TARGET (2022)
Pavements	Share of Interstate NHS pavements in good or poor condition	Measure includes roughness, rutting/ faulting, and cracking calculations. A segment of pavement is poor if two out of three measures are poor. A segment is good if all three measures are good.	Good: 60.1% Poor: 0.9%	N/A	Good: 55% Poor: 2%
Pavements	Share of non-Interstate NHS pavements in good or poor condition	Same as above	Good: 53.4% Poor: 1.3%	Good: 50% Poor: 4%	Good: 50% Poor: 4%
Bridges	Share of NHS bridge deck area in good or poor condition	Measure is based on NBI condition ratings of bridge structures 20 feet and greater	Good: 48.0% Poor: 1.9%	Good: 50% Poor: 4%	Good: 50% Poor: 4%

Although MnDOT anticipates meeting the federal targets, there are risks that could cause MnDOT to miss them. These risks include poor weather, such as a severe winter or flooding, and changes in funding. Given the short-term nature of the targets, the likelihood of these risks occurring and significantly impacting statewide asset condition are small. Another risk is that MnDOT is currently unable to forecast future condition for the federal pavement performance measure. The federal targets are in line with the current conditions for pavements but future condition could be higher or lower than expected with programmed projects.

Pavement and Bridge Targets and Expected Outcomes

MnDOT has been using performance measures and targets to guide decision making for over a decade. The pilot TAMP modified existing targets for pavement and bridge and recommended targets for other assets that have not previously had performance measures and targets. These recommendations were incorporated into the 2017 MnSHIP and used to estimate capital investment need on the state highway system. These performance targets can be thought of as a desired state of good repair for the highway system although funding limitations do not allow the department to meet every target.

Each year, MnDOT develops the 10-year Capital Highway Investment Plan which identifies 10 years worth of capital projects on the state highway system. Using these projects and their anticipated benefits, MnDOT is able to project future condition for many assets included in this plan. The section below describes the difference between MnDOT's pavement and bridge targets and the 10-year expected outcome.

PAVEMENT TARGETS

As part of the pilot TAMP, MnDOT recommended setting a target of no more than 2 percent poor pavement on the Interstate system and no more than 4 percent poor on the non-Interstate NHS (see Figure 7-2). While slightly less aggressive than the previous targets used to calculate need in MnSHIP, maintaining this level of condition represents a performance standard that is consistent with traveler expectations and MnDOT's strategic goals and objectives.

MnDOT also recommended adopting a non-NHS pavement condition target of no more than 10 percent poor as part of the pilot TAMP. This target, which is a slightly higher than existing conditions, is less aggressive than the no more than 3 percent poor target MnDOT had historically used to calculate needed investment in non-NHS pavement. Adopting a less aggressive pavement condition target on the non-NHS reflects federal and state policy, directing MnDOT to focus its resources on priority networks (e.g., NHS). Outreach

SYSTEM	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
Interstate	1.1%	≤ 2%	5.3%
Non-Interstate NHS	1.7%	≤ 4%	6.8%
Non-NHS	4.4%	≤ 10%	9.1%

conducted as part of MnSHIP also found that a majority of MnDOT's external stakeholders are willing to trade pavement condition on lower volume roads for a more well-balanced investment approach in other performance areas such as bridge condition, pedestrian facilities, and other non-motorized transportation.

Unlike the targets for Interstate and non-Interstate NHS pavement condition, a no more than 10 percent poor target on the non-NHS will likely be met under existing revenue projections. MnDOT expects the share of non-NHS roadway miles with poor pavement condition to increase from 4.4 percent in 2017 to 9 percent in 2027. While consistent with MnSHIP 2017 investment priorities, this outcome poses significant user costs 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 expected outcome in this performance area.

MnDOT's performance measure for pavement is not the same as the federal measure. MnDOT's measure focuses on ride quality and does not include rutting/faulting or cracking. The current conditions and future outcomes for MnDOT measure cannot be compared to the federal measure.

BRIDGE TARGETS

The pilot TAMP recommended no changes to MnDOT's bridge condition targets. The current targets (Figure 7-3) are consistent with MnSHIP 2017 investment priorities. MnDOT expects to be slightly above condition targets for NHS bridges while meeting condition targets for non-NHS bridges. Compared to current condition, MnDOT expects the share of NHS deck area on poor condition bridges to increase from 2 percent in 2017 to 5.1 percent in 2027. The share of non-NHS deck area on poor condition bridges is expected to increase from 3.4 percent to 8.9 percent. Both expected outcomes are well above targets, which illustrates the need for additional funding (see Chapter 8).

MnDOT's performance measure for bridges is substantially the same as the federal measure.

Figure 7-3: Bridge Condition Targets

SYSTEM	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
NHS	2.0%	≤ 2%	5.1%
Non-NHS	3.4%	≤ 8%	8.9%

Note:
Figure 7-3 reports condition by deck area of bridge structures 10' and greater and does not include bridge culverts or locally-owned NHS bridges (see Figure 2-10)

Other Asset Targets and Outcomes

MnDOT has chosen to develop performance measures and targets for assets beyond bridge and pavement. The pilot TAMP included targets for highway culverts, deep stormwater tunnels, and overhead sign structures.

Since the completion of the pilot TAMP, MnDOT has worked diligently to identify targets for additional assets and refine targets for assets included in the pilot TAMP. Expert work groups for each asset identified a recommended performance target that considered current and anticipated conditions, risk, and capital and maintenance investment. These assets include high mast light tower structures, buildings, ITS, noise walls, pedestrian infrastructure, traffic signals, and lighting.

MnDOT also convened a workshop to verify all proposed asset targets, while considering associated risks, to ensure that target decisions are made with a broad cross-asset perspective. This workshop included asset-specific work groups, the TAMP Advisory Group and members of MnDOT's Asset Management Steering Committee. The target setting methodologies are described in more detail for each asset below.

HIGHWAY CULVERT AND DEEP STORMWATER TUNNEL TARGETS

Figure 7-4 presents the current condition, performance targets and expected outcomes for MnDOT's highway culverts and deep stormwater tunnels. Performance targets for the condition of these assets were recommended as part of the pilot TAMP and adopted in MnSHIP 2017. These targets were established with expert judgment of the hydraulics work group, which also considered risks to the trunk highway system. For deep stormwater tunnels, the pilot TAMP recommended that MnDOT establish targets in line with those for highway culverts. This target represented a substantial improvement over the condition at that time; however, a plan has been implemented to systematically address deep stormwater tunnel needs which has substantially improved performance.

Figure 7-4: Highway Culverts and Deep Stormwater Tunnels Condition Targets

ASSET	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
Highway Culverts	15%	≤ 10%	12%
Deep Stormwater Tunnels	19%	≤ 10%	N/A%

Note:
Figure 7-4 shares "N/A" as a 10-year expected condition for deep stormwater tunnels. This is due to unpredictable deterioration modeling on these assets.

OVERHEAD SIGN STRUCTURES TARGETS

Figure 7-5 presents the current condition, performance target and expected outcome for MnDOT's overhead sign structures. Performance targets for the condition of these assets were defined during the development of MnSHIP. This TAMP, reflecting the expert judgment of the asset expert work group, sets a target of no more than 6 percent of overhead sign structures in 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.

Figure 7-5: Overhead Sign Structures Condition Targets

ASSET	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
Overhead Sign Structures	28%	≤ 6%	18%

HIGH-MAST LIGHT TOWER STRUCTURES TARGETS

Figure 7-6 presents the current condition, performance target and expected outcome for MnDOT's high-mast light towers. At the time of the development of the pilot 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. Since 2014, the expert work group developed and recommended a performance target for these assets which aligns with overhead sign structures since they carry similar risks.

Figure 7-6: High-Mast Light Tower Condition Targets

ASSET	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
High-Mast Light Tower Structures	18%	≤ 6%	N/A*

*MnDOT is unable to estimate future condition due to unpredictable deterioration of these assets.

BUILDINGS TARGETS

All nine building sub-categories had differing target setting methodologies. One commonality is that they were set by thorough discussion by asset experts and a cross-asset target analysis was taken into consideration.

Rest areas are the most visible building assets to the public. Therefore, it was decided that they should have a more aggressive target, allowing only a few to enter poor condition. There was a recent investment in weigh stations, keeping most of them out of poor condition. The desired target allows one weigh station to be in poor condition.

For all other buildings, critical sub-categories that deliver essential services have more aggressive targets to allow fewer assets to enter poor condition. Asset experts took into consideration which buildings are habitable or non-habitable, prioritizing according to user impact. Desired targets are worse than current condition accounting for a high number of buildings being in the fair condition categories, therefore requiring more maintenance over the next 10 years.

Figure 7-7: Building Condition Targets

ASSET	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
Class 1 Rest Areas and TICs - smaller buildings (< 4000 SF) that consist of a lobby, rest rooms, mechanical room and small office/storage space.	12%	≤ 4%	26%
Weigh Stations - smaller (< 4000 SF) two-level building, upper level consisting of work area for monitoring vehicles coming through scale, office space, break room and rest room. The lower level usually has a mechanical room, locker room and access to the scale pits.	0%	≤ 15%	29%
Small Truck Storage - small crew area (Truck Stations, State Sign Shop, Metro Fleet Bldg. and Bridge Crew Buildings).	1%	≤ 5%	15%
Large truck storage - maintenance shops and an area of office space either on one or more levels (Headquarters, Central Shop, Materials Research Lab and some larger truck stations).	0%	≤ 3%	12%
Salt Shelters - mainly treated wood structures, wood walled with post and metal bar joist roof structure, and fabric covered truss shelter (which has become our standard).	10%	≤ 15%	47%
Storage (heated or unheated) - minimal heating equipment such as unit heaters or space heaters. Unheated buildings range from pole barn structures to storage sheds.	4%	≤ 10%	10%
Office Buildings - for the most part, the entire building has finishes consistent with a typical office building.	0%	≤ 0%	0%
Other - all of these buildings vary greatly and don't easily fit into one of the other categories above.	15%	N/A	N/A

ITS TARGETS

Figure 7-8 presents ITS asset conditions and targets. Like buildings, ITS has several sub-categories with different target setting methodologies. The term, "approaching or beyond useful life," is used throughout ITS sub-asset classes, and refers to MnDOT's age-based rating scale. Over time, obsolescence results in shorter useful lives as technology changes accelerate.

User impact was a large factor in ITS target setting. For example, several sub-categories were prioritized due to significant public safety issues if they become non-operational. Reversible road gates and intersection warning systems are continuously monitored and are maintained or replaced immediately. Seasonal factors were also considered for several assets that are unable to be maintained in the winter months, allowing them to fall into poor condition during that time.

Figure 7-8: ITS Condition Targets

ASSET	2017 CONDITION (% APPROACHING OR BEYOND USEFUL LIFE)	TARGET (% APPROACHING OR BEYOND USEFUL LIFE)	10-YEAR EXPECTED OUTCOME (% APPROACHING OR BEYOND USEFUL LIFE)
Fiber communication network (miles)	10%	≤ 4%	20%
Fiber network shelters	10%	≤ 5%	30%
TMS (traffic management system) cabinet	13%	≤ 7%	20%
Dynamic message signs	15%	≤ 7%	20%
Traffic monitoring cameras	10%	≤ 5%	35%
Traffic detector stations/site -loops and radar (5 mobile units not included in count)	4%	≤ 2%	25%
Communication equipment - Ethernet backbone devices - Ethernet communication equipment - Video transmission equipment - Video en/decoding devices (pairs)*	20%	≤ 5%	40%
MnPASS readers	0%	≤ 2%	10%
Reversible road gates	0%	= 0%	0%
Ramp meters	0%	≤ 2%	0%
Intersection warning systems	0%	≤ 6%	Not available**
Road weather information systems sites	0%	≤ 2%	0%
Automatic traffic recorders	N/A	≤ 10%	Not available**
Weigh-in-motion system sites	N/A	≤ 10%	Not available**
Road closures	0%	≤ 10%	Not available**

Note:
* En/Decoding devices being phased out with switch from analog to IP traffic cameras)
**With the anticipated funding availability for ITS replacements over the 10 years of the TAMP, the 10-year expected outcomes for ITS overall will be a higher percentage of devices in poor condition than the 2017 conditions. Because spending priorities can be shifted among the various ITS device types, the TAMP cannot reliably predict the 10-year expected outcome for the individual ITS device types.

NOISE WALLS TARGETS

The noise wall target of 8 percent poor as shown in Figure 7-9 is based on accepted risk. Risk is dependent on wall location as some walls may fall into private property, other structures, or frontage roads if they fail. Condition is measured using a health index score which does not consider aesthetics. A majority of funding is currently spent on replacement or major rehabilitation. Target-setting encourages more money to be spent on preventive maintenance to extend the life of noise walls.

Figure 7-9: Noise Walls Condition Targets

ASSET	2017 CONDITION (% POOR)	TARGET (% POOR)	10-YEAR EXPECTED OUTCOME (% POOR)
Noise Walls	11%	≤ 8%	17%

PEDESTRIAN INFRASTRUCTURE TARGETS

The Americans with Disabilities Act is the main driver for pedestrian infrastructure condition targets. Desired targets were set in alignment with ADA compliance standards (substantial and full compliance), which are outlined in the ADA Transition Plan. MnDOT understands that there are locations throughout the state that limit the ability to reach substantial compliance due to geographic slopes and existing infrastructure. Approximately 10 percent of pedestrian assets exist in these locations and are not considered in target setting.

Figure 7-10: Pedestrian Infrastructure Condition Targets

ASSET	2017 COMPLIANCE (% NON-ADA COMPLIANT)	TARGET (% NON-ADA COMPLIANT)	10-YEAR EXPECTED OUTCOME (% NON-ADA COMPLIANT)
Pedestrian Infrastructure	61% Curb Ramps 44% Sidewalks	≤ 6% Curb Ramps ≤ 5% Sidewalks	39% Curb Ramps 19% Sidewalks

TRAFFIC SIGNALS AND LIGHTING TARGETS

Figure 7-11 presents the current condition, performance target and expected outcome for MnDOT's signal and lighting assets. An age-based approach is used for signals and lighting. When setting the target, the asset work group considered at what age the asset can still function, but is no longer cost-effective to continue to maintain. This is deemed the asset's useful life. The useful life for both signals and lighting is 30 years.

Figure 7-11: Traffic Signals and Lighting Condition Targets

ASSET	2017 CONDITION (% BEYOND USEFUL LIFE)	TARGET (% BEYOND USEFUL LIFE)	10-YEAR EXPECTED OUTCOME (% POOR)
Traffic Signals	16%	≤ 2% beyond useful life (30 years or older)	13%
Lighting	31%	≤ 2% beyond useful life (30 years or older)	24%

Performance Gap Summary

As mentioned above, MnDOT expects to meet its federal two and four year targets for bridge and pavement condition. There is no expected performance gap for these measures and targets.

MnDOT's state targets and investment levels are set as part of the MnSHIP process. These state targets are MnDOT's desired state of good repair and may or may not be acheivable given projected funding levels. The ten-year asset performance outcomes in this chapter show that the MnSHIP investment levels for many assets are not sufficient to meet the state targets. In order to minimize the risks associated with not meeting the state targets, MnDOT has identified optimization strategies to strech available revenue. These strategies are discussed in Chapter 8: Financial Plan and Investment Strategies. In addition, MnSHIP established maintaining and repairing existing assets as a high priority for spending additional revenue. Any revenue above the expected ten-year levels should benefit the asset condition outcomes through additional investment.

Chapter 8

FINANCIAL PLAN AND INVESTMENT STRATEGIES

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FINANCIAL PLAN AND INVESTMENT STRATEGIES

Overview

When developing investment priorities in MnSHIP, MnDOT accounts for various factors that include revenue trends, federal and state law, level-of-service provided by the system, key risks to the highway system, and public input. Over the next 10 years, MnDOT will balance investments in preservation and maintenance of the existing highway system with other priority investment objectives.

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 return on investment in the long term. 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. Trade-offs between investment areas, performance levels, public expectations, and risks play a significant role in MnDOT's ability to achieve lowest life cycle costs (discussed in Chapter 2).

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 (2027).

Revenue Sources

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

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

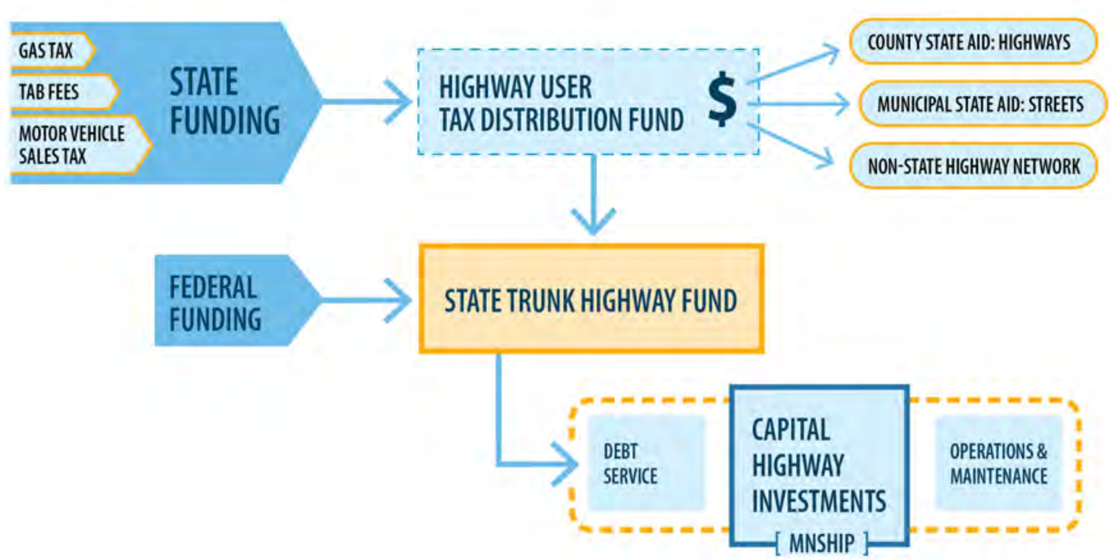
The revenues from Federal-aid go directly to the State Trunk Highway Fund (see Figure 8-1), which funds capital improvements on the state highway system. Revenues from the main state sources, as well as various smaller revenues, are pooled into the Highway User Tax Distribution Fund and divided between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

Approximately 5 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.

MnDOT also occasionally receives short-term state highway funds from general fund transfers to the Highway User Tax Distribution Fund. Recently, this occurred during the 2017 Minnesota legislative session. It is difficult to project the frequency and size of these transfers into the future. This plan assumes that the general fund transfer is continued through 2027.

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



Revenue Trends

Revenue growth continues to be slow. There are several explanations for why MnDOT expects revenues to grow more slowly between 2018 and 2037 as compared to previous years. These include:

- **Improvement of vehicle fuel efficiency.** 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 program. While improved fuel economy means lower vehicle air pollutant emissions and a positive impact on the environment, improved fuel economy also means fewer gas taxes collected, and the gas tax is one of the major sources of both federal and state revenue for transportation.
- Increase in hybrid and electric vehicles. Due to advances in engine and battery technologies, hybrid and electric vehicles are becoming more popular. These vehicles, whose lowered emissions are more environmentally friendly, consume less or no fuel. As a result, they contribute fewer revenues to the State Trunk Highway Fund.
- People are driving about the same distance. There was significant growth in the number of vehicle miles traveled on the highway system in the 1990s and early 2000s; however, this growth leveled off in 2004. While per capita VMT remains about the same, total VMT has shown a slight increase in the past couple of years. Total VMT is still expected to increase along with economic and population growth over the next 20 years, but per capita VMT is projected to remain relatively flat due to demographic, technological, and behavioral changes. As a result, state motor fuel excise taxes will grow but not drastically. Federal-aid revenues, based on motor fuel excise taxes and transfers from the U.S. General Fund, are also expected to grow slowly over the next 20 years; increases in recent years are far less than decades past.

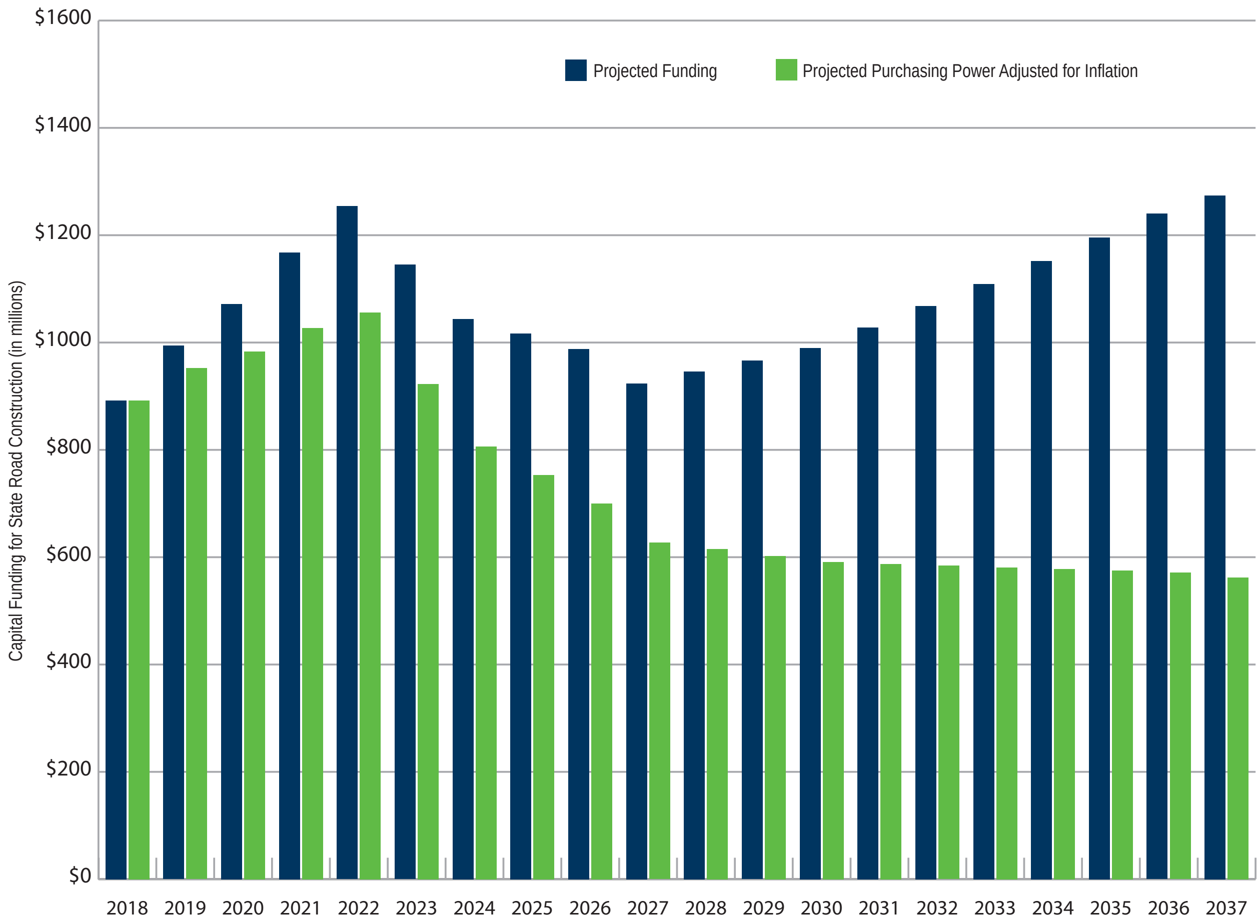
Revenue and Inflation

CAPITAL

Over the next 10 years, MnDOT estimates that $9.8 billion in revenue will be available for capital investment on the state highway system – approximately $980 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.

MnDOT anticipates that the actual amount of funding it receives from the State Trunk Highway Fund will increase by approximately 2 percent per year over the next 10 years. 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, and labor) continue to grow at an annual rate of approximately 4.5 percent—a slight tapering off from the past decade—exceeding the annual revenue growth rate of approximately 2 percent. This imbalance was also a factor in the 2013 Minnesota State Highway Investment Plan, and is expected to persist as a long-term planning challenge. Figure 8-2 illustrates the impact of 4.5 percent inflation on

Figure 8-2: Anticipated Construction Funding by Year Including Adjustments for Inflation



annual buying power (blue) versus nominal funding (green) in future years of construction. The net effect is that inflation will erode over half the buying power of funding by 2037, given the assumptions stated above. Figure 8-3 illustrates annual construction revenue over the next 10 years.

Figure 8-3: Anticipated Construction Revenue

FISCAL YEAR	CONSTRUCTION REVENUE
2018	$901
2019	$892
2020	$955
2021	$1,054
2022	$1,004
2023	$963
2024	$976
2025	$1,002
2026	$1,017
2027	$1,037

Note: Revenue is listed in millions. Based on 2018-2027 Capital Highway Investment Plan.

OPERATIONS AND MAINTENANCE

MnDOT has a maintenance and operations workforce of approximately 2,000 employees spread across eight districts. A priority service provided is clearing of snow and ice from the trunk highway system, and staffing levels are set with snow and ice operation as a priority.

The same workforce, when not performing winter duties, is tasked with additional asset management responsibilities including:

- Pavement preventive maintenance (primarily crack sealing)
- Pavement reactive maintenance (several different methods)
- Bridge preventive maintenance
- Bridge reactive maintenance
- Culvert and drainage system preventive maintenance
- Culvert and drainage system reactive maintenance
- Sign maintenance and replacements
- Traffic barrier reactive maintenance
- Highway striping and message placement
- Other operational activities such as debris removal and vegetation control

During preparation of the pilot TAMP, MnDOT concluded that it needed better integration between its capital and maintenance investment decisions. Accordingly, a substantial effort was made to capture and model maintenance costs in direct relation to asset condition for pavements, bridges, culverts, overhead sign structures and high-mast tower lighting.

For example, MnDOT can estimate five different cost levels for reactive maintenance to pavements based on their condition ratings. During MnSHIP preparation, MnDOT applied the cost models to the forecasted conditions to yield information about expected future demands for that part of the organization. This process is early in its evolution, and as such has not been used to set budgets or make trade-off decisions. However, that is MnDOT's goal for all asset classes maintained by internal staff.

This work has also been applied to an effort called "Total Cost of Ownership," where a representative roadway design (such as suburban freeway) is assessed by combining Life Cycle Planning for all asset classes with cost models for all maintenance and operations activities. This allows MnDOT to realistically evaluate the impacts of system expansion proposals.

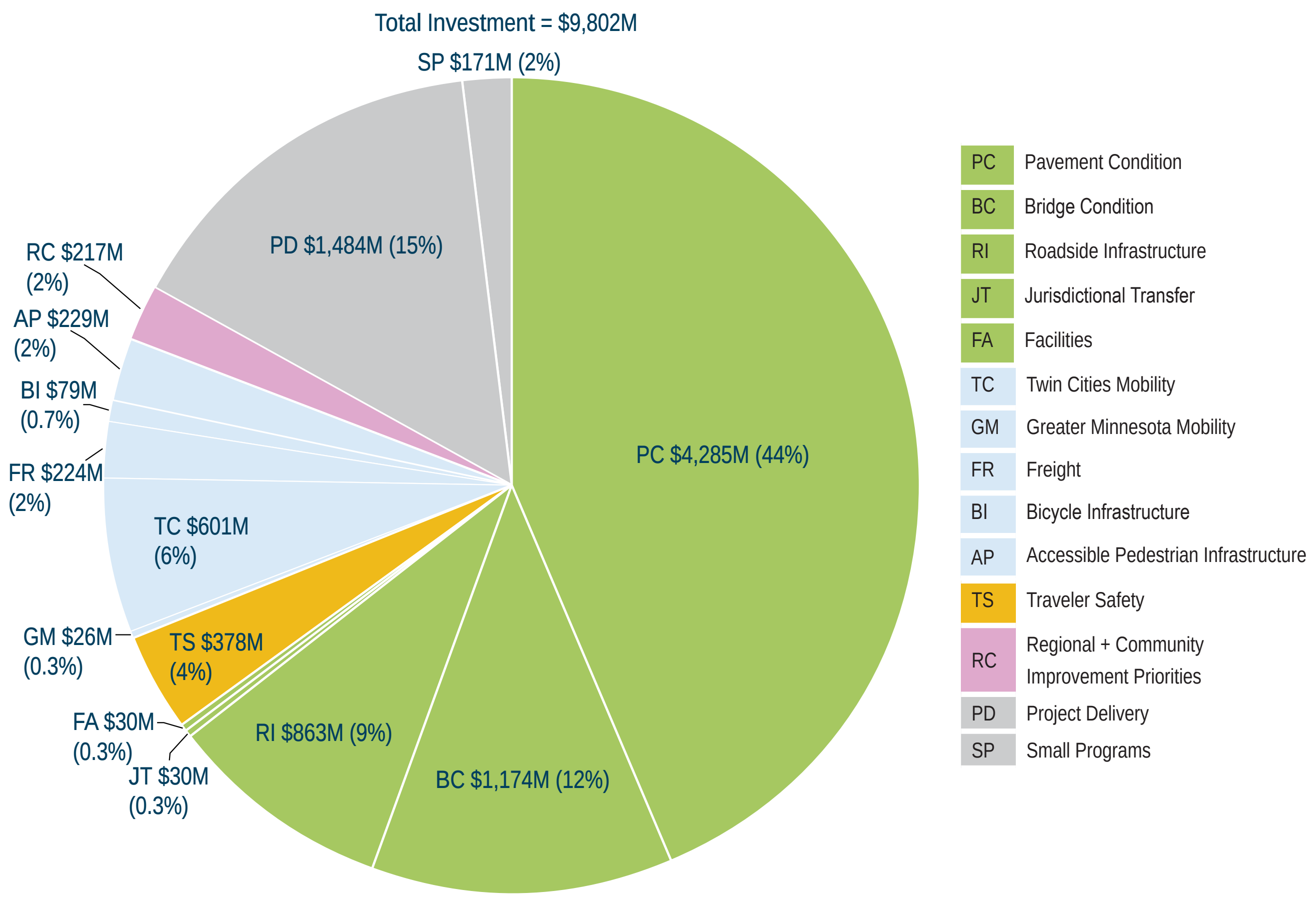
Through application of Geographic Information Systems and other tracking systems, MnDOT has worked to formalize the tracking, costs, program coordination, production commitment, and benefit accounting of preventive work, which is an integral part of minimizing the life cycle costs of maintaining assets. This effort will continue to be refined as asset inventories are completed and the use of the TAMS is expanded across the enterprise.

Given a relatively recent focus on asset management, improvements in technologies and additional information gathering opportunities, MnDOT is beginning to create measures and targets that will optimize resource allocations for the benefits of the infrastructure. A recently completed Asset Management Gap Assessment, funded through the FHWA, identified six priority process improvements. MnDOT is aggressively pursuing these developments, and each will make a significant improvement in how the department prioritizes work, maintains assets, and manages technologies and data.

Funding Program Overview

MnDOT invests in state highway projects through two primary programs: the Statewide Performance Program and the District Risk Management Program. The purpose of establishing these two programs is to ensure the agency efficiently and effectively works toward common statewide goals - in particular, meeting identified outcomes of the MnSHIP investment direction while maintaining some flexibility to address unique risks and circumstances at the district level. Figure 8-4 shows the planned investments during the time frame covered by the TAMP (2018-2027).

Figure 8-4: 2018-2027 Planned Capital Investments



STATEWIDE PERFORMANCE PROGRAM

MnDOT created the Statewide Performance Program in 2013 to respond to changes in federal requirements. Federal legislation places greater emphasis on National Highway System performance and requires MnDOT to make progress toward national performance goal areas, including those related to condition, safety and travel time reliability on the NHS. Failure to do so results in the loss of some federal funding flexibility. The SPP manages investment and project selection on the NHS to meet statewide outcomes listed in the MnSHIP investment direction.

MnDOT selects projects that continue its progress towards meeting the outcomes identified in MnSHIP on the NHS. Staff from MnDOT's central office, district offices, and specialty offices collaborate to develop a list of potential projects and planned investments to address these risks through the SPP. MnDOT adds new SPP projects annually in year 10 of the CHIP. Existing projects continue year by year through the CHIP. Each MnDOT district coordinates with Area Transportation Partnerships, Metropolitan Planning Organizations, and other key partners to make recommended adjustments to project scope and timing. Upon final selection for inclusion in the STIP, each MnDOT district is responsible for designing and delivering the selected projects.

DISTRICT RISK MANAGEMENT PROGRAM

The SPP focuses funding on addressing key performance targets on NHS routes, but the DRMP focuses funding on all other non-NHS highways and other non-performance-based needs on all state highways. The majority of the program supports pavement and bridge rehabilitation or replacement projects. The DRMP project selection process is structured to give districts the flexibility to address their greatest regional and local risks. Districts are also able to make additional investments on the NHS if the proposed project is in response to a high-risk issue. MnDOT distributes different levels of funding to the districts for this program based on a Resource Distribution Formula that accounts for various system factors (Figure 8-5). The funds each district receives for programming its DRMP projects are determined through this target formula.

The Resource Distribution Formula considers five factors: a district's projected condition for non-NHS pavement, a district's projected condition for non-NHS bridges, a district's portion of total trunk highway lane miles, vehicle miles traveled (VMT), and heavy commercial VMT. The amount allocated to each district depends on these factors, according to the breakdown below.

Figure 8-5: Resource Distribution Formula Factors

DISTRIBUTION FACTOR	PERCENT OF FORMULA	DATA SOURCE
Non-NHS Pavement Condition	20%	2016 data for 2022-2027 average annual funding needed to reach 60% good, 10% poor from Materials Pavement Model
Non-NHS Bridge Condition	20%	2016 data for 2022-27 bridge funding needs based on remaining service life to reach 50% good, 8% poor
Trunk Highway Lane Miles	30%	2016 lanes miles
Vehicle Miles Traveled	24%	2014 VMT on all roads
Heavy Commercial VMT	6%	2013 HCVMT (State highways only)

MnDOT revises the distribution annually with updated data from that year, and applies the distribution to years 5-10 in the CHIP. DRMP funding in the first four years in the current CHIP remain unaffected. The process is designed this way to give districts fixed funding in years 1-4 for programming and finalizing the scope of projects. This also ensures that there is a more accurate reflection of remaining needs in each district as projects get completed and pavement and bridge conditions improve or decline each year. The districts see moderate changes in funding in each subsequent year as the data being used is updated annually with projected conditions.

Investment Priorities and Direction

MnDOT's primary emphasis for the next 20 years is on the preservation and maintenance of the existing state highway system. MnSHIP continues a shift for MnDOT from being a builder of the system to being the maintainer and operator of the system. This approach reflects MnDOT and stakeholder input while meeting key requirements and agency commitments.

MnDOT manages the state highway system to minimize the percent of pavement miles and bridge deck area in poor condition. Through MnSHIP, MnDOT estimated the investment needed to reach percent poor targets on the Interstate, remaining NHS and non-NHS by 2037 to be $13.44 billion for pavements and $2.65 billion for bridges. Over this same period, MnDOT projects to only be able to investment $10.31 billion on pavements and $2.38 billion on bridges given the additional need to invest in priorities such as new safety infrastructure, ADA compliance of existing pedestrian infrastructure and new mobility improvements. Figure 8-6 shows the need and the investment yearly average. MnDOT did not break out the investment or need by fiscal year or work type as MnSHIP is a high level investment plan. Yearly investment guidance and project work type are determined through the project selection and development process.

Figure 8-6: Average Pavement and Bridge Need and Planned Investment in MnSHIP

ASSET	AVERAGE YEARLY NEED	AVERAGE YEARLY INVESTMENT	20-YEAR NEED TOTAL	20-YEAR INVESTMENT TOTAL
Pavements	$672 million	$516 million	$13.44 billion	$10.31 billion
Bridges	$133 million	$119 million	$2.65 billion	$2.38 billion

A majority of available resources are directed to asset management categories–primarily Pavement Condition, Bridge Condition, and Roadside Infrastructure Condition. The Roadside Infrastructure category includes highway culverts, deep stormwater tunnels, overhead sign structures, high-mast light tower structures, ITS, signals, lighting, noise walls as well as a number of other asset categories not included in this TAMP. Facilities includes investment for rest areas, weigh stations, and scales.

Asset Investment Strategies

Pavement and bridge conditions in Minnesota are relatively well-understood and documented according to long-standing condition surveys and databases. Information from the pavement management system is used by the districts to determine the appropriate type of work and level of repair for each pavement section. Since 2010, MnDOT has been developing, refining, and implementing its Bridge Replacement and Improvement Management 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.

MnDOT's asset management approach is not without limitations. Capital investment decisions identified in Figure 8-4 do not consider non-capital funded maintenance activities. The life cycle planning 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. Other asset management improvements 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

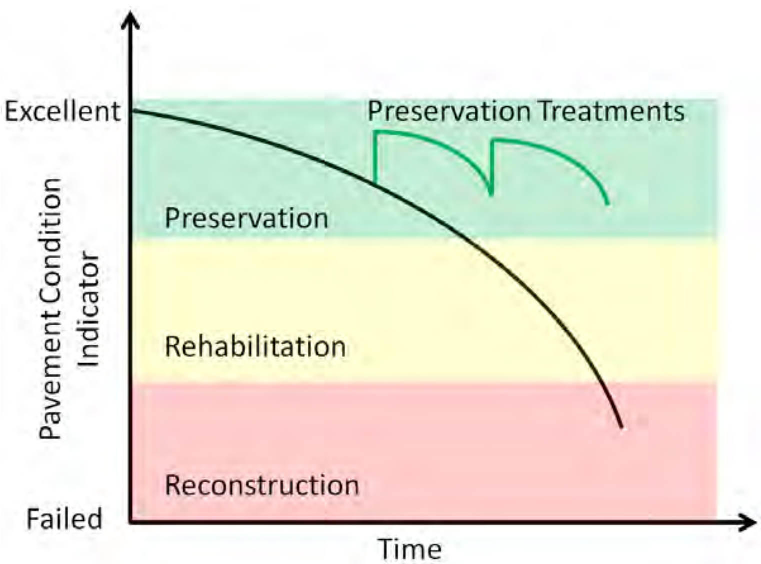
MnDOT's Highway Pavement Management Application (HPMA – discussed in Chapter 2) is used to determine the investment needs and outcomes developed for MnSHIP. A conceptual model of typical pavement deterioration is shown in Figure 8-7.

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 trade-offs to be considered when developing a balanced investment plan:

- Constrained Budget: Because MnDOT is working with a constrained budget and maintaining a road in good condition is most cost-effective (see Chapter 6), the department strives to make investments 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 projects are based on several factors: asset condition, annual average daily traffic, safety, the economic importance of the highway corridor, other infrastructure needs, and customer satisfaction.

- Pavement Age and Condition: Approximately 60 percent of Minnesota's state highways were constructed over 50 years ago, 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. Substantial levels of reactive pavement maintenance are increasingly required as pavement conditions worsen below an RQI of 3.2.

Figure 8-7: Deterioration Model Illustrating Impact of Preservation



- 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.

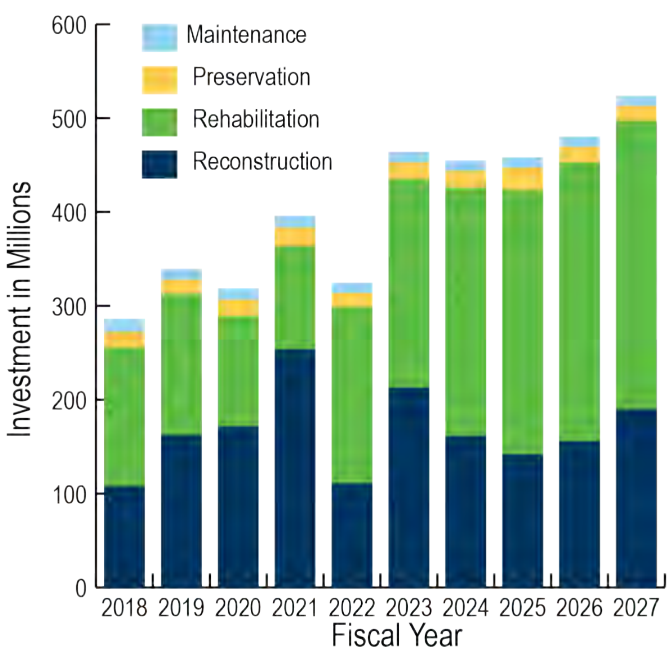
- Performance Targets: To meet established performance targets, a good portion of the investment has to be made in major rehabilitation and reconstruction activities, which tend to have a greater effect on overall network condition when compared to maintenance and preservation activities. MnDOT is currently working to add additional long-term

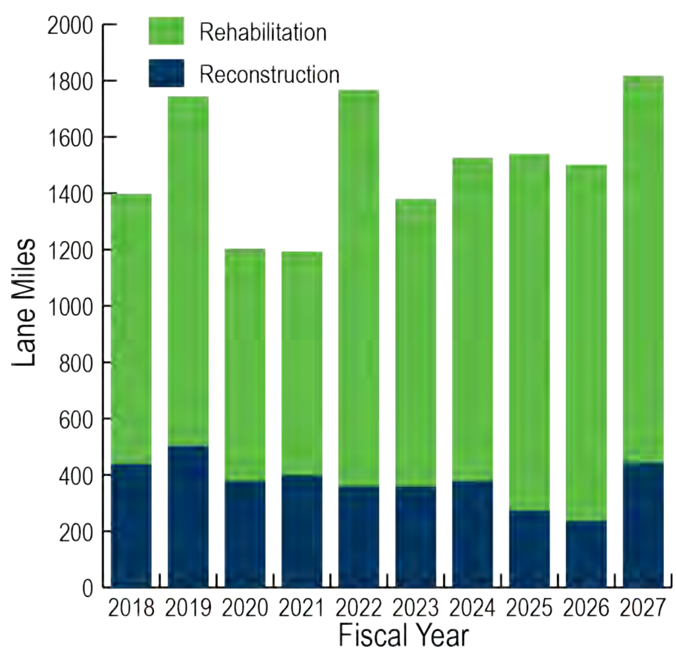
measures, as well as a policy that will speak to the appropriateness of trading some short term target achievement for longer term cost effective investment strategies.

- **Preventive Maintenance:** MnDOT districts use this capital set-aside 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. The model takes into account the amount of planned district investment towards preventive maintenance. Preventive maintenance is supplemented by MnDOT maintenance, which is funded through the operations budget. MnDOT is working to enhance the accounting for the effects of preventive maintenance in its pavement modeling.

Between 2018 and 2027, MnDOT identifies capital pavement expenditures of $548 million on Interstate pavements, $1.7 billion on the non-Interstate NHS and $1.7 billion on the non-NHS system, for a total of $4.0 billion. Investments in pavement maintenance will total approximately $117 million and includes yearly setasides for seasonal road repairs. Breaking the investment out by type of fix, MnDOT anticipates investing $1.7 billion on reconstruction projects, $2.1 billion on rehabilitation projects, and $176 million on preservation over the next 10 years. Figure 8-8 shows yearly investment and lane miles addressed by work type. Preservation work includes activities such as crack filling, joint sealing, and chip seals that help to slow pavements from deteriorating from

Figure 8-8: Yearly Pavement Investment and Lane Miles by Work Type

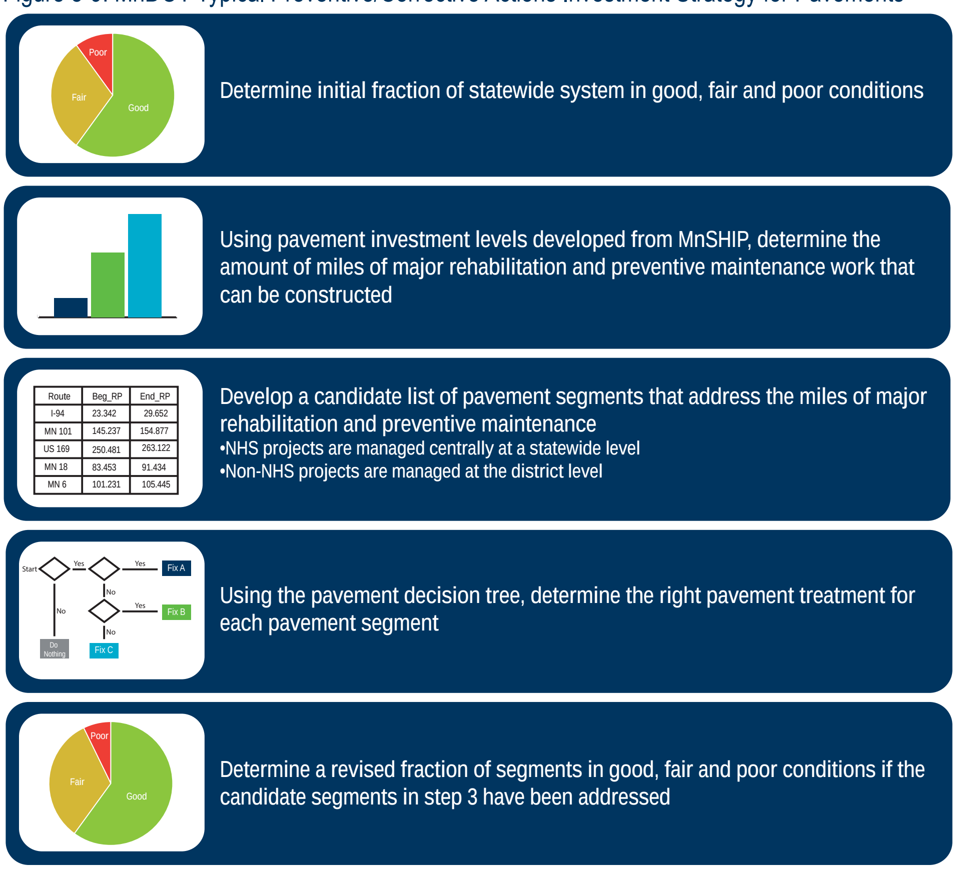




good to fair condition. Each district sets aside funding for annual preventive maintenance work. Rehabilitation work includes activities such as mill and overlays of various thicknesses, concrete pavement repairs, concrete panel replacement, or cold in-place recycling. Reconstruction work includes activities such as replacement of the entire roadway, reclaims, or unbounded overlays. MnDOT is unable to estimate the amount of lane miles to be completed with preservation or maintenance investments. Most of the investments are held in yearly setasides for projects to be identified in the future. MnDOT does not generally identify preservation or maintenance projects more than a year in advance.

The percent of pavements in poor condition decreased slightly in 2017, continuing the improvement trend since 2012. Pavement condition is expected to decline on all systems through 2027. NHS pavements are expected to decline at the fastest rate through 2021. From 2021 to 2027, pavement condition are expected to stabilize. Overall, MnDOT expects projected pavement condition levels to meet two-and four-year federal pavement targets and maintain Interstate pavement condition below the federal threshold of 5 percent. The typical strategy used by MnDOT to determine the location of pavement investments is summarized in Figure 8-9.

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



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
- 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 as documented in the Pavement Preservation Manual
- Integrate maintenance, operations and capital decision-making
- Employ lower-cost long-term life cycle 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
- Identify opportunities to combine work to improve multiple asset classes (i.e., bridges, culverts or curb ramps) to limit disruptions and gain efficiencies

BRIDGES

Investment needs and outcomes for bridges were established using MnDOT's bridge management system for bridge inventory and condition data, and MnDOT's Bridge Replacement and Improvement Management system for prioritization and cost estimates.

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. Preventive maintenance work tends to slow the rate of deterioration, but does not prevent damage from eventually taking place. If timely repairs are made, conditions can be improved, thus extending the service life. Eventually, age and deferred maintenance cause a bridge to slip into a poor condition where only expensive rehabilitation and replacement can restore the needed level of performance.

Preservation actions can be funded from either the capital budget or the operations budget, depending on the magnitude of the work. Approximately $10 million - $12 million is spent each year on preventive and reactive bridge maintenance from MnDOT's operations budget. Inspections constitute another $2 million - $3 million out of the operations budget. The size of this budget has traditionally been based on management experience rather than objective analysis. However, MnDOT considers preventive maintenance as the next highest priority following inspections and critical maintenance and has employed a strong preservation culture for many years by accomplishing key activities, such as flushing, crack sealing, joint sealing, rail sealing, joint maintenance, and other minor repairs on a regular schedule for a majority of its bridges. Even with these commitments, preservation, as a whole, is under-funded for bridges and would benefit from improved planning tools to correctly size the budget, select the best candidates for preservation and produce a more balanced investment plan. The typical strategy used by MnDOT to develop investment levels for bridges is summarized in Figure 8-10. MnDOT is continually working to improve data collection, analysis, reporting, and performance measure tools to promote improved planning and investment.

For years 2018-2027, MnDOT envisions capital and maintenance bridge expenditures of $695 million on the NHS and $362 million on non-NHS bridges, for a total of $1.1 billion. Broken out by type of project, MnDOT is projected to invest $100 million in maintenance projects, $130 million in preservation projects, $215 million in rehabilitation projects, and $530 million in reconstruction projects. Figure 8-11 show yearly investment and square feet of deck area by work type. Preservation work includes activities such as bridge painting, deck overlays, joint replacements, substructure repairs, and railing or median replacements. Rehabilitation work includes activities such as deck replacement, super structure replacement, or major widening. Reconstruction work includes replacement of bridges or bridge culverts.

The percent of bridge deck area on the National Highway System in poor condition increased slightly in 2017. Performance on the NHS is expected to decline slightly below the target but still meet the federal two-and four-year targets. As future investments prioritize the NHS, the condition of bridges on non-NHS routes is expected to worsen but still remain below the target through 2023. As noted previously, MnDOT's bridge condition targets state that no more than 2 percent of NHS bridge deck area and 8 percent of non-NHS bridge deck area should be in poor condition.

Figure 8-10: MnDOT Typical Preventive/Corrective Actions Investment Strategy for Bridges

Figure 8-11: Yearly Bridge Investment and Deck Area by Work Type

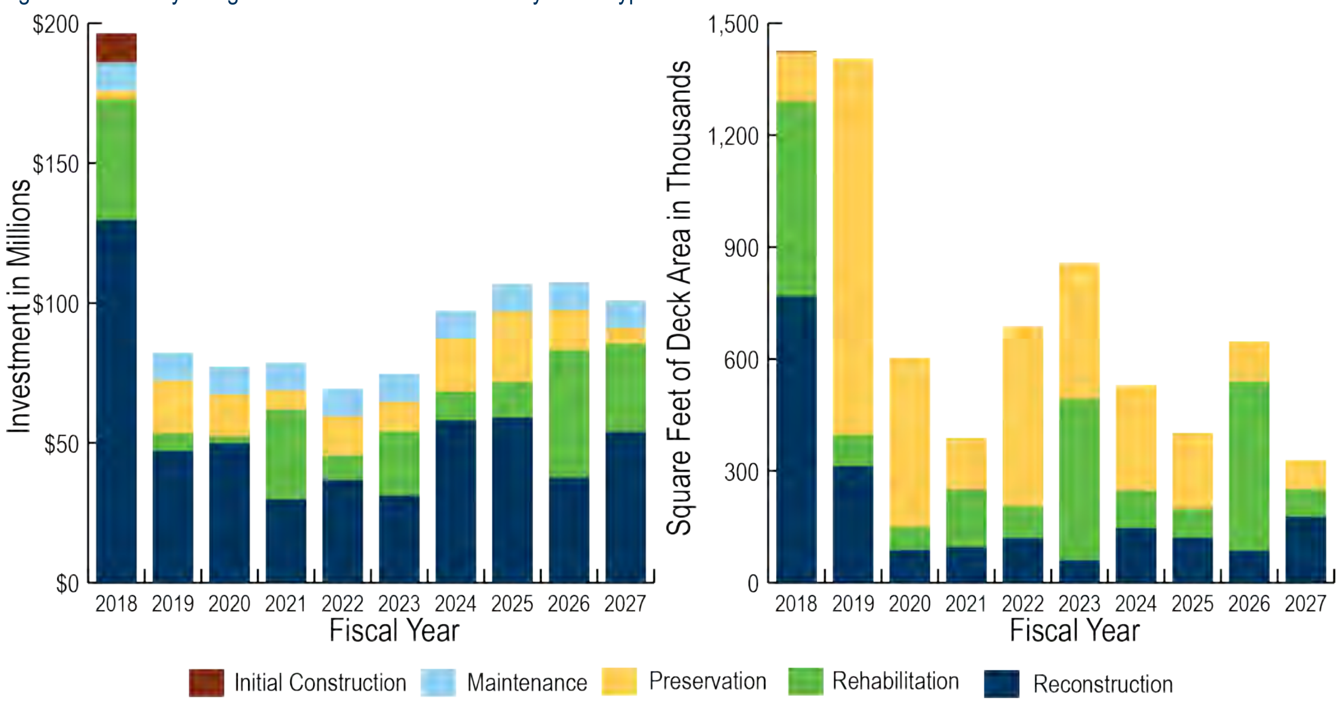


Figure 8-12: Amount of Maintenance Completed Per Year

ANNUAL MAINTENANCE OF DECK AREA
9,426,00 square feet

Note: Maintenance work type assumes 20% of deck area treated annually with deck crack sealing. See Figure 6-12 for frequency of other maintenance treatments.

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 and reactive maintenance
- Invest in preservation and 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

OTHER INFRASTRUCTURE

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 category. Approximately $700 million is included for capital funding of roadside infrastructure work through 2027. Operations and maintenance 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 $290 million over the 10-year period, with an additional $4.5 million needed for deep stormwater tunnels, given the recommended targets.

Overhead Sign Structures and High-Mast Light Tower Structures

These structures exhibit long service lives with minimal maintenance. 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 2018 to 2027, MnDOT expects capital and maintenance funding of $8 million for overhead sign structures, and needs an additional $33 million to meet the condition target. An investment need has not been determined for high-mast light tower structures.

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

- Using recycled materials, innovative design, and preventive maintenance treatments to extend the useful life of infrastructure without increasing costs
- Coordinate investments with other projects where economies of scale exist to reduce unit costs
- Repair and replace infrastructure in poor condition or infrastructure beyond its service life
- Replace infrastructure with greatest exposure to the traveling public, mostly through pavement/bridge projects

Noise Walls

Noise walls are a supporting asset on the state highway system. When a noise wall declines, the majority of the decay occurs below the ground. While visual impairments such paint chipping are obvious, the wood post density and deterioration drive the need for wall replacement.

For the 10 years from 2018 to 2027, MnDOT expects capital and maintenance funding of $97 million for noise walls, and needs an additional $57 million to meet the condition target. Currently no funding is directed to noise wall preventive maintenance activities and all funds are used for replacement or major rehab. Depending on the need, up to 10 percent of the available funding could be used for noise wall preservation activities such as plank/batten repair (loose nails/screws), sealing on concrete posts etc.

Signals & Lighting

Traffic signals and lighting are supporting assets on the state highway system. For the 10 years from 2018 to 2027, MnDOT expects capital and maintenance funding of $157 million for signals, and needs an additional $78 million to meet the condition target. MnDOT expects capital and maintenance funding of $125 million for lighting, and needs an additional $19 million to meet the condition target.

Pedestrian Infrastructure

Pedestrian infrastructure includes reconstructed and new infrastructure to ensure safe, accessible, and convenient options for pedestrians travelling along or across state highways. The majority of funding is targeted at existing infrastructure on a needs basis as pavement projects are constructed. Typically, this includes sidewalk and pedestrian ramp replacement where needed. Filling any gaps in the system (new sidewalks) takes place only where there is a clearly identified need such as missing infrastructure or connections across barriers. Preservation activities include horizontal sawing, mud-jacking of sidewalk, sidewalk panel replacements, and general vegetation maintenance. These maintenance activities can greatly impact the usability of the pedestrian system. However, these activities are currently less frequent than sidewalk replacement and there are not set levels of investment in maintenance.

For the 10 years from 2018 to 2027, MnDOT expects capital and maintenance expenditure funding of $250 million for pedestrian infrastructure, and an additional $250 million to meet the condition target.

MnDOT may draw from the following strategies, when necessary, to prioritize projects and address risks that are associated with lower performance or investment in Accessible Pedestrian Infrastructure:

- Focus more investment in sidewalks, curb ramps, and APS projects
- Make other pedestrian improvements via complete streets and complete gaps in the network

Buildings

A portion of MnSHIP funding for rest areas and weigh stations and bonding will be used on site improvements that are not buildings and will not affect the condition of the buildings.

For the 10 years from 2018 to 2027, MnDOT expects capital and maintenance expenditure funding of $261 million for buildings, and an additional $132 million to meet the condition target.

ITS Infrastructure

Intelligent Transportation Systems are supporting assets on the state highway system, helping to improve efficiency, and safety. For the 10 years from 2018 to 2027, MnDOT expects to spend $41 million in capital and maintenance funding. An additional $67 million is needed to meet targets.

Summary

Figures 8-13 and 8-14 summarize planned 10-year capital investments to achieve pavement, bridge, and other asset targets. MnDOT manages the condition of assets and calculates unmet need over a 20 year time frame in MnSHIP so additional investment totals in the TAMP (Figures 8-13 and 8-14) may not match totals in MnSHIP for all assets. Pavements on the non-NHS system are projected to still be meeting the target of less than 10% poor through 2027. It is not anticipated that non-NHS pavements will need additional investment over the next 10 years but will need additional investment in the future to acheive the target by 2037.

Figure 8-13: Pavement and Bridge Planned and Needed Investment to Achieve Targets by 2027

ASSET	CURRENT CONDITION	TARGET RECOMMENDATION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Pavement: Interstate	1.1% poor	≤ 2% poor	$548 million	$199 million
Pavement: Non-Interstate NHS	1.7% poor	≤ 4% poor	$1.7 billion	$902 million
Pavement: Non-NHS	4.4% poor	≤ 10% poor	$1.7 billion	$0
Pavement: Total	N/A	N/A	**$4.0 billion**	**$1.1 billion**
Bridge: NHS	2% poor	≤ 2% poor	$695 million	$367 million
Bridge: Non-NHS	3.4% poor	≤ 8% poor	$362 million	$84 million
Bridge: Total	N/A	N/A	**$1.1 billion**	**$451 million**

Note: More detail on sub assets and targets can be found in Chapter 4

Figure 8-14: Other Assets Planned and Needed Investment to Achieve Targets by 2027

ASSET	CURRENT CONDITION	TARGET RECOMMENDATION	PLANNED INVESTMENT	ADDITIONAL INVESTMENT NEEDED TO REACH TARGETS
Highway Culverts	15% poor	≤ 10% poor	$254 million	$37 million
Deep Stormwater Tunnels	19% poor	≤ 10% poor	$2 million	$2.5 million
Overhead Sign Structures	28% poor	≤ 6% poor	$8 million	$33 million
High-Mast Light Tower Structures	18% poor	≤ 6% poor	N/A	N/A
Noise Walls	11% poor	≤ 8% poor	$97 million	$57 million
Traffic Signal Systems	16% poor	≤ 2% poor beyond useful life (30 years or older)	$157 million	$78 million
Lighting	31% poor	≤ 2% poor beyond useful life (30 years or older)	$125 million	$19 million
Pedestrian Infrastructure	Varies	Varies	$250 million	$104 million
Buildings	Varies	Varies	$261 million	$132 million
ITS Infrastructure	Varies	Varies	$41 million	$67 million
Other Assets: Total	N/A	N/A	$1.2 billion	$530 million

Note: More detail on sub assets and targets can be found in Chapter 4.

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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

To comply with MAP-21, the FHWA will review the TAMP development process and certify that it meets the U.S. Secretary of Transportation's requirements. The process used to develop and maintain the TAMP will be reviewed and certified at least once every four years (or as major revisions are necessary); FHWA will identify specific actions that are necessary to correct any deficiencies. FHWA will also conduct an annual consistency determination which evaluates implementation of the TAMP. Additionally, MAP-21 required that states make significant progress toward achieving their performance targets for the National Highway System.

While meeting federal requirements was certainly an objective, MnDOT's primary focus in developing this plan is to continually improve the life cycle management of its transportation assets. Therefore, governance responsibilities have been extended beyond those required under the legislation, and has resulted in creation of the Asset Management Project Office, which created plans for expanding the assets that are covered in future TAMPs and for monitoring the agency's success towards asset management goals. In addition, AMPO is responsible for operationalizing asset management and implementing the Transportation Asset Management System.

The pilot TAMP 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 development and other asset management initiatives. The Steering Committee has been established and is led by MnDOT's Modal Planning and Program Management, Engineering Services and Operations Division Directors, and includes 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 continues to be important. The Steering Committee reports directly to the Division Director champions and MnDOT's Senior Leadership Team, and meets on a regular basis to address the following:

- Review TAMP progress to ensure that MnDOT is meeting federal requirements
- Establish a regular cycle for updating the TAMP in conjunction with updates to MnSHIP and other relevant documents
- Develop and implement guidance for expanding the TAMP to include other transportation assets; this guidance includes 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 authority for governance of the TAMP, the Steering Committee has been 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 continued communication and accountability for each of the assets included in the TAMP.

The Steering Committee worked with several units of the Office of Transportation System Management and the larger Modal Planning and Program Management Division to coordinate the update with MnSHIP, ensuring that the TAMP recommendations are used to drive future investment plans. As 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 CHIP.

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. Figure 9-1 displays the priority strategies identified in the pilot TAMP that have since been completed. This work highlights MnDOT's commitment to improving asset management processes and eliminating gaps.

Figure 9-1: Completed Priority Strategies for Mitigating Risks

RISK MITIGATION STRATEGY	PURPOSE(S)
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)
Develop and adequately communicate construction specifications for overhead sign structures and update for 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)
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 trade-off 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
Retighten loose nuts of high-mast light tower structures, overhead sign structures, light poles, and **traffic signals**	To assure the structures are adequately anchored down to the foundations to avoid structural failure, premature fracture and fatigue failure, and to prolong the life expectancy of these structures
Incorporate large bridge culverts into bridge condition	To include large bridge culverts in the overall % poor condition for bridges
Develop an inventory process for deep stormwater tunnels	To improve regularity of deep stormwater tunnel inspections by adding the tunnel system to TAMS, with inspection frequency tied to reported condition

Note: 10 feet or greater in span length, but no more than 20 feet, or are non-automobile bridge

Figure 9-2 offers more detail on new and remaining priority strategies, including responsible offices, expected time frames, and estimated implementation costs. Time frames 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 TIME FRAME	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	$5,000 (staff time)
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 Metro District	1-3 years	$150,000 (for study)
Track overhead sign structures and high-mast light tower structures in a Transportation Asset Management System	To more deliberately and effectively manage these asset categories; to include more assets in TAMS, thereby improving cross-asset trade-off decision-making	MnDOT Office of Transportation System Management; MnDOT Districts	2-4 years	$150,000
Develop retiming schedule for statewide **traffic signals**	To reduce traffic congestion and collisions	MnDOT Office of Traffic Engineering	1-2 years	$50,000 staff time
Develop a Transportation Research Synthesis on **traffic** signal preventive maintenance in other agencies	To better manage assets so that they do not prematurely deteriorate and cause unforeseen traffic incidents and/or congestion	MnDOT Office of Traffic Engineering	3-4 years	$10,000
Develop a statewide **traffic** signal and lighting checklist for construction project engineers and/or inspectors to use when signing off during construction and after completion	To better manage assets so that they do not prematurely deteriorate and cause unforeseen traffic incidents and/or congestion	MnDOT Office of Traffic Engineering	3-4 years	$50,000 staff time
Develop a statewide ITS system sample plan and standard details/specification, including performing integration (built on the ITS Design Manual)	To reduce the likelihood of ITS equipment becoming inoperable before the end of expected service life which would create uncertainty for financial budgeting and forecasting	MnDOT Office of Traffic Engineering	2 years	$700,000

PRIORITY LEVEL 1 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIME FRAME	ESTIMATED COST
Conduct a study to determine building operation deficiencies, site condition, and future needs for gap assessment (used for scoping and project prioritization process)	To better manage buildings appropriately/efficiently reducing deferred maintenance and added cost to the agency	Building Services	1-2 years	$250,000 for staffing or consultant
Implement Archibus and develop a project prioritization process for existing as well as any new funding for buildings	To manage buildings appropriately/efficiently to reduce the likelihood of safety risks to users, deferred maintenance, and added costs to agency	Building Services	1-2 years	$250,000

PRIORITY LEVEL 2 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIME FRAME	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 include in pavement management decisions in order to achieve the lowest life cycle cost	MnDOT Metro District	18 Months	$2,000,000 (assuming 2000 miles)
Provide support, tools, and reports for management of highway culverts in TAMS	To more deliberately and effectively manage highway culverts using the full functionality of TAMS; to refine the business process and asset management tools (such as decision tree)	MnDOT Bridge Office	1-2 years	$35,000
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 – Various Districts	Currently underway	$150,000 staff time
Identify optimal preventive maintenance protocols for lighting, including a resource demand model (i.e., materials, parts, etc.), and/or TRS on preventive maintenance	To establish a formal inspection program for lighting structures based on MnDOT's best knowledge of structure condition, deterioration rates and inspection needs	MnDOT Office of Traffic Engineering	3-4 years	$50,000 staff time

PRIORITY LEVEL 2 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIME FRAME	ESTIMATED COST
Develop an inspection/cycle protocol based on condition or age and TAMS. The protocol includes ADA ramps, curbs, sidewalks and other pedestrian infrastructure needs (include: frequency, who is responsible for activities, costs and other pertinent information)	To meet the needs of system users, including the disabled community. Failure to do so results in an unsafe system, loss of trust, and increased legal liability for MnDOT	ADA Personnel	3 years	$20,000
Develop an inspection/maintenance cycle protocol that would identify which noise walls should be inspected/maintained, including a staffing need/gap assessment based on inspection/maintenance protocols	To use a noise wall maintenance strategy that inspects at appropriate frequencies, addresses fixes in a timely manner and reduces the potential for a legislative audit	MnDOT Maintenance – Various Districts	10-year cycle	$50,000 in year 1, then $50,000/year thereafter
Conduct education/training and a construction sign-off (i.e., liaison) or contract compliance protocol for noise walls	To eliminate poor contract execution (e.g., inappropriate specifications and construction installation) that results in sub-par or out of compliance assets. Sub-par assets add costs to MnDOT and create a safety concern for public traveling along and adjacent to noise walls	MnDOT Maintenance – Various Districts	Ongoing	$250,000

PRIORITY LEVEL 3 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIME FRAME	ESTIMATED COST
Repair or replace highway culverts in accordance with recommendations from the TAMS	To improve overall system quality and management; to meet newly established and vetted asset targets	MnDOT Maintenance – Various Districts; MnDOT Bridge Office	10 years	$290,000,000
Develop a statewide resource demand model for **traffic** signal retiming (personnel, consultant contracts, etc.)	To reduce traffic congestion and collisions	MnDOT Office of Traffic Engineering	5-6 years	$200,000
Develop and increase **traffic** signals and lighting staffing resources with proficient knowledge to be able to extract and use information from TAMS to better manage the assets	To better manage assets so that they do not prematurely deteriorate and cause unforeseen traffic incidents and/or congestion	MnDOT Office of Traffic Engineering	3-4 years	$500,000 in new and existing staff
Identify and integrate pedestrian infrastructure measures, targets, and needs into MnSHIP and MnDOT program delivery process	To address system gaps with future funding to ensure mobility options and meet public expectations	ADA Personnel	3-5 years	Approximately $500,000
Develop an ADA/pedestrian infrastructure guide that identifies the appropriate process (i.e., consent agreement), types of ADA/ complete streets improvements by corridor, urban-rural, etc.	To receive local consent to ensure operations/maintenance and oversight of the system and prevent premature deterioration and unsafe conditions for users	ADA Personnel	1 year	Approximately $50,000 (already underway)
Develop an inspection/ maintenance-cycle protocol, which would identify what ITS assets should be inspected/ maintained, including a staffing need/gap assessment based on inspection/maintenance protocols	To manage assets to the lowest life-cycle costs, slow deterioration and keep up with necessary repairs or technology	Office of Traffic Engineering	1-2 years	$200,000

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 9-4. Time frames and costs for these broad improvements have not been estimated.

Figure 9-4: 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 trade-off analyses (more comprehensive trade-off analyses will be possible as asset registers and risk assessments are completed for additional asset categories)	MnDOT Office of Transportation System Management
Explore scenario planning for BRIM	To improve long-range planning and investment decision-making for bridges across the state	MnDOT Bridge Office

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)
- Enhance cross-asset prioritization
- Clarify what maintenance cost should be considered in asset management. Some possible inconsistencies between TAMP asset groups

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
- Implement the latest findings on pavement rehabilitation techniques

Bridges

- Better understanding of impact of maintenance activities on bridge performance and life cycle costs
- Enhance deterioration curves by using bridge element level data and develop curves for elements with high chloride exposure

Hydraulic Infrastructure

- Development of deterioration models for various types of culverts and tunnels
- Better understanding of impacts of various maintenance, preservation and rehabilitation 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 preventive maintenance performed on these structures in varying ages and conditions

Noise Walls

- Study the difference between the structural integrity and the noise blocking effectiveness of walls.
- Analyze how effective older walls (that might be in fair or poor condition) are at blocking noise
- Develop a risk assessment and priority list that looks at the criteria of noise blocking abilities of walls versus just examining the condition
- Study how to proactively address access issues that impede regular access to noise walls
- Determine how painting and battening noise walls impacts aesthetics
- Examine deterioration curves over time and see if the curves could be used in the future to predict condition/life cycle
- Examine opportunities to formally adopt an inspection program with specific inspection frequency
- Study how roadway proximity may predict deterioration rates

Signals and Lighting

- Test a smart lighting system for Metro District to monitor power usage, dim, and turning lights on/off
- Test moving more signals to the central traffic signal control system
- Study formalizing a structural inspection program for signals and lighting and implement a uniform structural condition rating
- Determine ways to enhance TAMS to make it easier to collect historical investments in maintenance activities

Pedestrian Infrastructure

- Determine where future expansion of the network will be planned (this will likely be addressed in the future Pedestrian System Plan)
- Research maintenance and maintenance agreement best practices

- Research scalability of maintenance workforce
- Identify a true sidewalk and ramp life-cycle
- Determine how to recognize and account for mid life-cycle treatments, such as panel replacements, that are outside of construction projects and/or are complaint-based
- Determine how to account for the addition and management of assets in pedestrian right of way such as safety and aesthetic enhancements (trees, lights benches, art, bicycle parking, transit stops, kiosks, planters, etc.)

Buildings

- Determine a method for incorporating other assets associated with the entire facility such as pavement, signage, lighting, scale mechanics, wastewater systems etc.
- Determine how to incorporate deferred maintenance identified in the TAMP process into the 20-year Building Services Section investment plan
- Expand understanding of life-cycle cost considerations with the consultant involved with developing 20-year BSS investment plan
- Develop a method for incorporating functionality of facility (including weigh stations and rest areas) into investment analysis (e.g., functional obsolescence of truck station would require new design not just replacement in kind)
- Research how to make best use of Facility Maintenance Program dollars
- Continue truck station location optimization
- Work with American Truck Research Institute to study truck parking needs to determine rest area locations and capacity

ITS

- Identify central point of contact for each ITS infrastructure systems and performance measures that are statewide (may be addressed through Transportation System Management and Operations Plan)
- Develop a documented consistent process for gathering the cost and expenditures for the assets. Solicit Finance to assist with gathering the information and the process. Would create an annual report that consist of the expenditures.
- Develop a separate source type for maintenance in MnDOT's Resource Consumption Application

- Determine a new timesheet code for ITS maintenance and leave 1501 as ITS operations
- Find a way to document other costs of ownership that are related to the system operation not the individual asset

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.

The following lessons learned during MnDOT's TAMP development process will greatly improve business processes and management practices as more assets are included in the TAMP process:

- 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 to help reduce the risk of failure. For assets without formal management processes in place, such as overhead sign structures, highway culverts, and deep stormwater tunnels, the TAMP framework served as a proof-of-concept for expanding the scope of future TAMPs.
- 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.
- MnDOT should continue striving 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.

- Continue investing in research studies to better understand deterioration of all assets, 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, overhead sign structures and high-mast light tower structures. Overhead sign structures must be inspected more consistently in order to anticipate problems that other agencies have found to be common, especially fatigue cracking.
- Life Cycle Planning 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.
- 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 funding 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.
- 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.
- 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 lighting poles, signal poles or ITS structures.

- The multi-disciplinary nature of the Steering Committee, Advisory Group 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.

- 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.

Moving Forward

The development of MnDOT's pilot TAMP has already improved and refined many aspects of the agency's policies and methods related to asset management. Further asset management planning has only solidified the principles of asset management at MnDOT. By demonstrating the value of life cycle planning, the TAMP has impacted 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 has moved forward with asset management planning since the pilot TAMP was completed in 2014, 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 Transportation Asset Management System, the TAMP 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.