DEPARTMENT OF TRANSPORTATION

DRAFT Transportation Asset Management Plan

April 2018

MinnesotaGO

A Collaborative Vision for Transportation

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DEPARTMENT OF TRANSPORTATION

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Saint Paul, MN 55155-1800

April 30, 2018

Arlene Kocher
Division Administrator
Federal Highway Administration- Minnesota Division
380 Jackson Street, Suite 500
St. Paul, Minnesota 55101

Dear Arlene,

I am pleased to present Minnesota Department of Transportation's draft 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 draft 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. 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 new process and look forward to receiving additional input from the FHWA Division Office on this draft.

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

Sincerely,

Charles A. Zelle
Commissioner

CC: Kris Riesenberg, FHWA

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Chapter 1

INTRODUCTION

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INTRODUCTION

Overview

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

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

On July 6, 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law. MAP-21 directed state transportation agencies and Metropolitan Transportation Organizations to develop a performance-based and multimodal program to address the many challenges facing the nation's transportation system.

MAP-21 required states to develop a risk-based transportation asset management plan (TAMP) for the National Highway System to improve or preserve the condition of the assets and the performance of the system. Figure 1-1 summarizes the characteristics and benefits of a transportation asset management program[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 (FAST) Act, enacted in 2015.

After the requirements for the TAMP were established in MAP-21, MnDOT was selected as a pilot state to develop a draft TAMP. This draft was completed in 2014 and shared publicly to help other states in TAMP development. 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.

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 and inform capital and operations planning efforts from this point forward. In addition to being a federal requirement, the TAMP is a planning tool by which MnDOT can more thoroughly evaluate risks and develop mitigation strategies, analyze life cycle costs, establish asset condition performance measures and targets and develop investment strategies. It formalizes and documents the following key information to meet 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

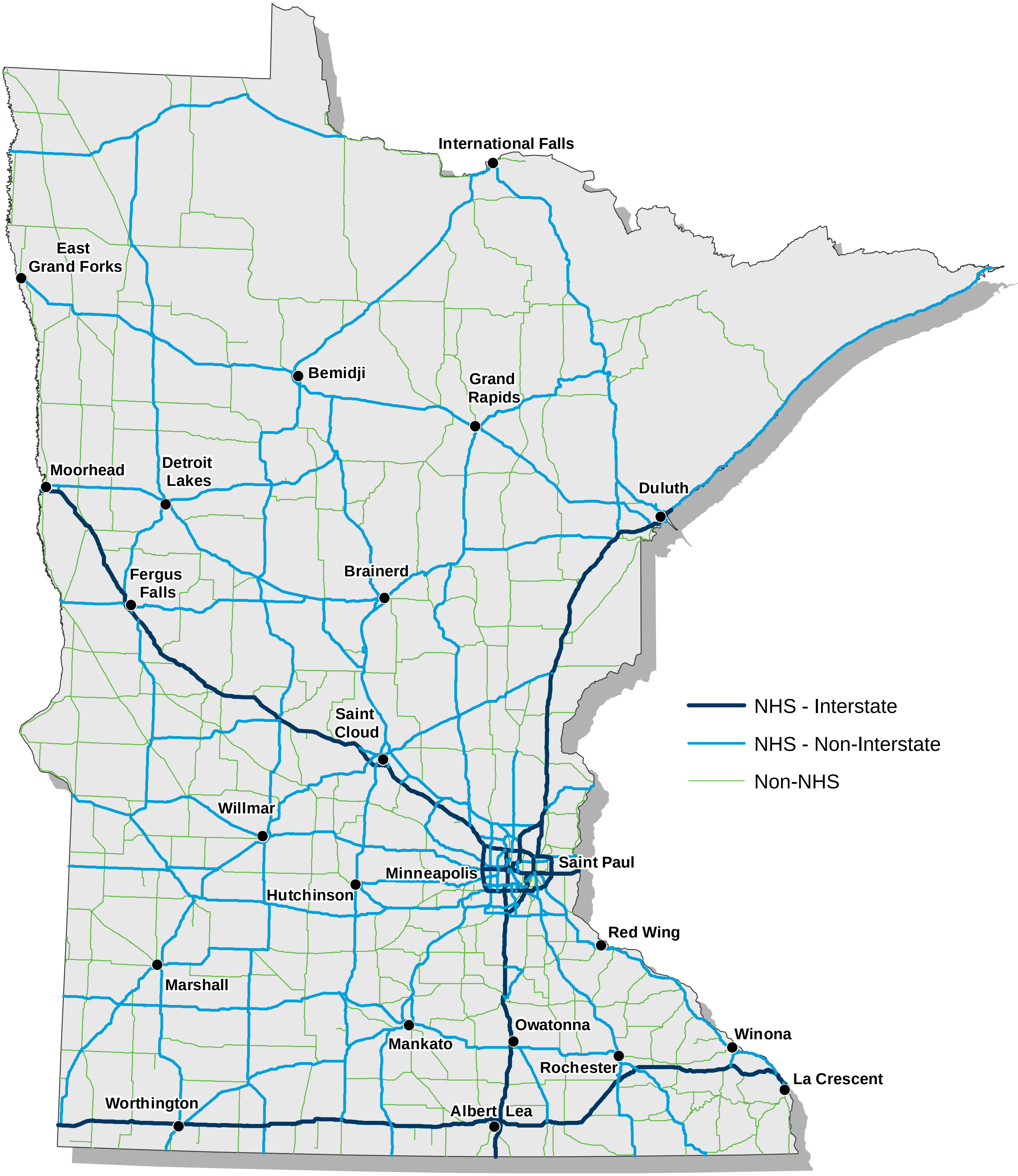
Characteristics of an Asset Management Program

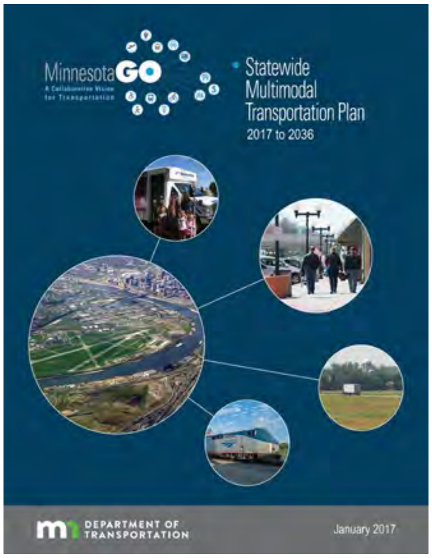
- Track system condition, needs and performance
- Consider public expectations and desires when setting strategic objectives
- Align agency investment decisions to achieve strategic goals
- Use an objective process to maintain and manage assets which considers needs, available funding, risks, operational 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

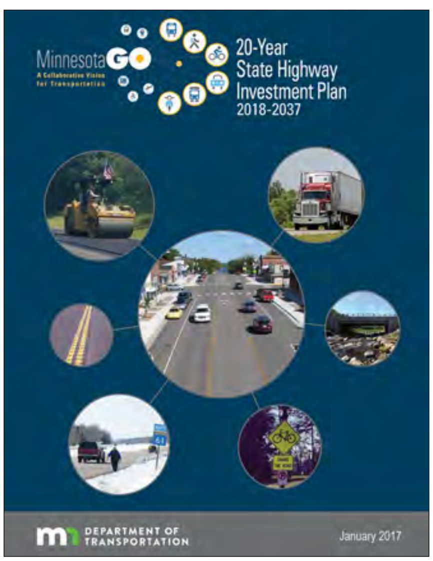
- Optimize and improve transportation system performance
- Improve customer satisfaction
- Minimize life cycle costs
- Match level of service provided to public expectations
- Make more informed, cost-effective program decisions and better utilize existing assets
- Develop an unbiased methodology to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

Figure 1-2: Minnesota's State Highway System





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



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

Asset Management Planning at MnDOT

MnDOT's asset management direction is established and continually updated through a statewide performance based planning process. The Minnesota GO Vision, Statewide Multimodal Transportation Plan and State Highway Investment Plan (MnSHIP) set policy objectives and performance based targets. The State Highway Investment Plan and the State Multimodal Transportation Plan are updated every five years. The Annual Minnesota Transportation Performance Report documents system performance and informs future policy and investment planning.

MINNESOTA GO VISION AND STATEWIDE MULTIMODAL TRANSPORTATION PLAN

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

STATE HIGHWAY INVESTMENT PLAN

The Minnesota State Highway Investment Plan (MnSHIP) is MnDOT's vehicle for determining and communicating capital investment priorities for the state highway system over a 20 year planning horizon. MnSHIP directs capital investment for Minnesota's state highway system over the next 20 years. The plan identified investment priorities given current and expected funding. MnSHIP describes how MnDOT will use capital investments to repair, replace and improve the 14,000-mile state highway system. The plan also includes an

estimate of the investment needs for the highway system based on the costs required to meet performance-based targets and other key system goals. MnDOT takes into account many factors in developing MnSHIP, including federal and state laws, MnDOT policy and current and projected conditions of the state highway system. The 20-year investment direction established in MnSHIP focuses on maintaining the existing state highway system while making limited mobility investments. Despite this level of investment in maintaining the existing state highway system, the condition of the system is expected to deteriorate over the next 20 years.

HIGHWAY SYSTEMS OPERATIONS PLAN

HSOP, completed in 2012, provided a framework for managing key operations and maintenance activities at MnDOT. It identified risks and recommended investment strategies as part of a short-term spending plan. Subsequent planning work has supplemented this plan including an agency-wide effort to apply asset management principles to maintenance investments and products and services.

ANNUAL TRANSPORTATION PERFORMANCE REPORT

The (2015) Annual Transportation Performance Report describes trends in the condition and service levels for Minnesota's transportation system. It summarizes the plans, investments, strategies and innovations MnDOT and its partners use to optimize performance, and tracks progress in five performance areas.

The Annual Performance Report notes the projected long-term decline of most asset conditions, particularly pavement.

Process

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

The pilot TAMP was the product of a 12 month process that involved a Steering Committee, Project Management Team and four technical Work Groups.

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

Steering Committee representation included:

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

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

Work Groups were developed for each broad asset category: pavement, bridge, hydraulics and other traffic structures. Each was comprised of subject matter technical experts and included at least one representative from the steering committee. Highway culverts and deep stormwater tunnels were discussed together with the Hydraulics Work Group, while overhead sign structures and high-mast light tower structures were discussed together by the Other Traffic Structures Work Group. These experts were integral in documenting current practices, determining data availability, assessing risks and proposing mitigation strategies, and identifying targets and investment strategies.

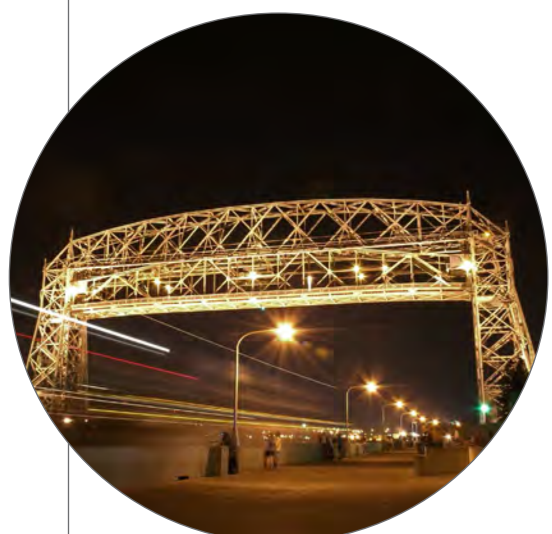
The pilot project resulted in the completion of a draft TAMP in 2014. A second phase of asset management planning, begun in 2016, expanded the scope of the TAMP to include buildings, pedestrian infrastructure, intelligent transportation systems, noise walls, signals and lighting.

In addition to the process described above, MnDOT created a TAMP Advisory Group to coordinate and communicate asset management planning across the agency, particularly to district staff.

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 (EAM) which is called MnDOT's Transportation Asset Management System (TAMS) 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., MnSHIP). 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 existing 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 existing performance measures and targets identified in MnSHIP and new TAMP target recommendations for consideration during development of the next MnSHIP.
- Chapter 8: Financial Plan and Investment Strategies – This chapter presents a financial outlook based on recent trends and assumptions, summarizes capital and maintenance investments for the next 10 years, and describes how different capital investment scenarios considered risk. It also outlines the committed revenue and revenue needs to meet expected performance outcomes over the next 10 years.
- Chapter 9: Implementation and Future Developments – This chapter summarizes the important actions or desired takeaways identified during the TAMP process beginning with the pilot. This chapter also identifies implementation steps to continually make progress toward better asset management. It also presents recommendations for future updates to the TAMP.

In addition to the pilot TAMP, a Technical Guide was prepared and published separately. The Technical Guide contained additional information on each chapter of the TAMP, and was included to supplement the pilot TAMP document.

Chapter 2

ASSET MANAGEMENT PLANNING AND PROGRAMMING FRAMEWORK

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ASSET MANAGEMENT OBJECTIVES

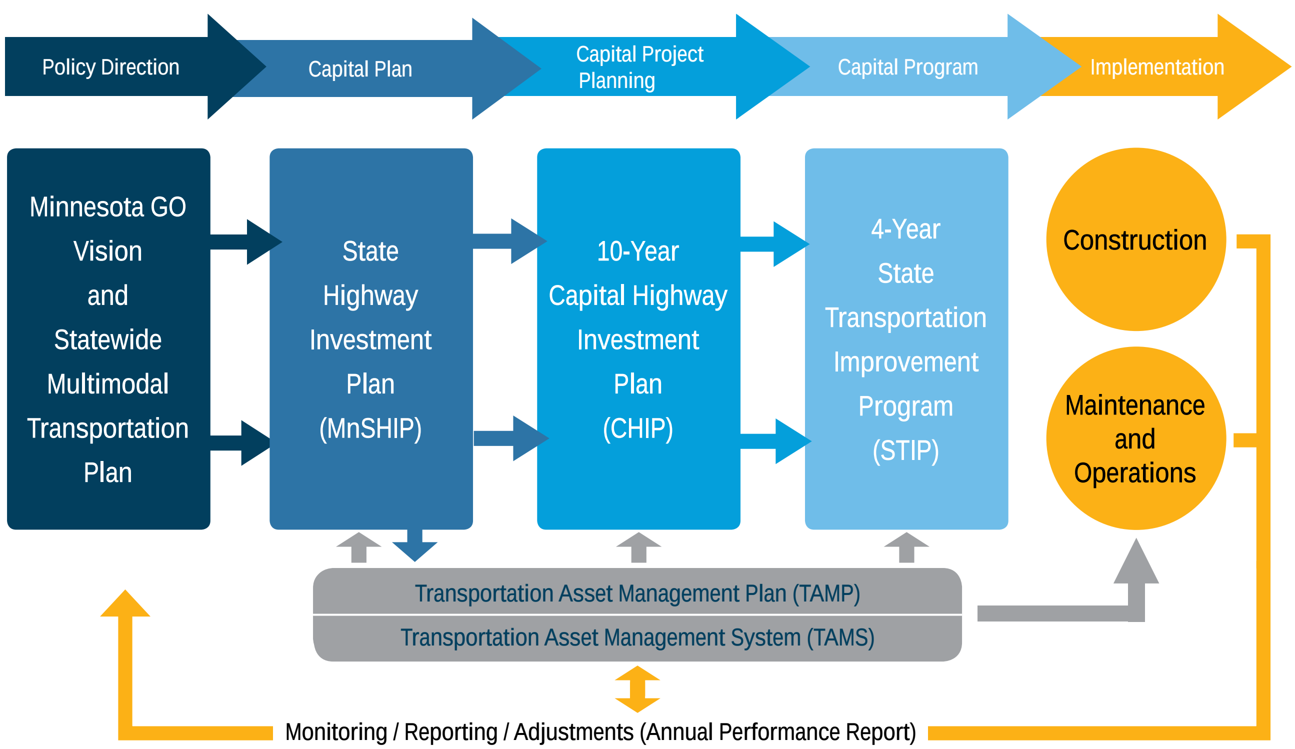
Overview

MnDOT has strong business processes in place to prioritize asset management investments in Minnesota's transportation infrastructure. Asset management is understood at MnDOT as the effective use of available resources to make the right investment decisions and minimize asset life cycle costs, while considering the various 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 priorities and objectives are reflected in its investment plans, which include the 20-year State Highway Investment Plan (MnSHIP) 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 (SMTP) – 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 2017 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 be able 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 provide a sustainable multimodal transportation system that improves the quality of life, environmental health and overall economic competitiveness of Minnesota. As outlined in the Minnesota GO Vision, the role of the transportation system is to:

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

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

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

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

STATEWIDE MULTIMODAL TRANSPORTATION PLAN

MnDOT's Statewide Multimodal Transportation Plan (SMTP), adopted in 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.

Transportation Safety

Safeguard transportation users and the communities the system travels through. 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.

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.

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

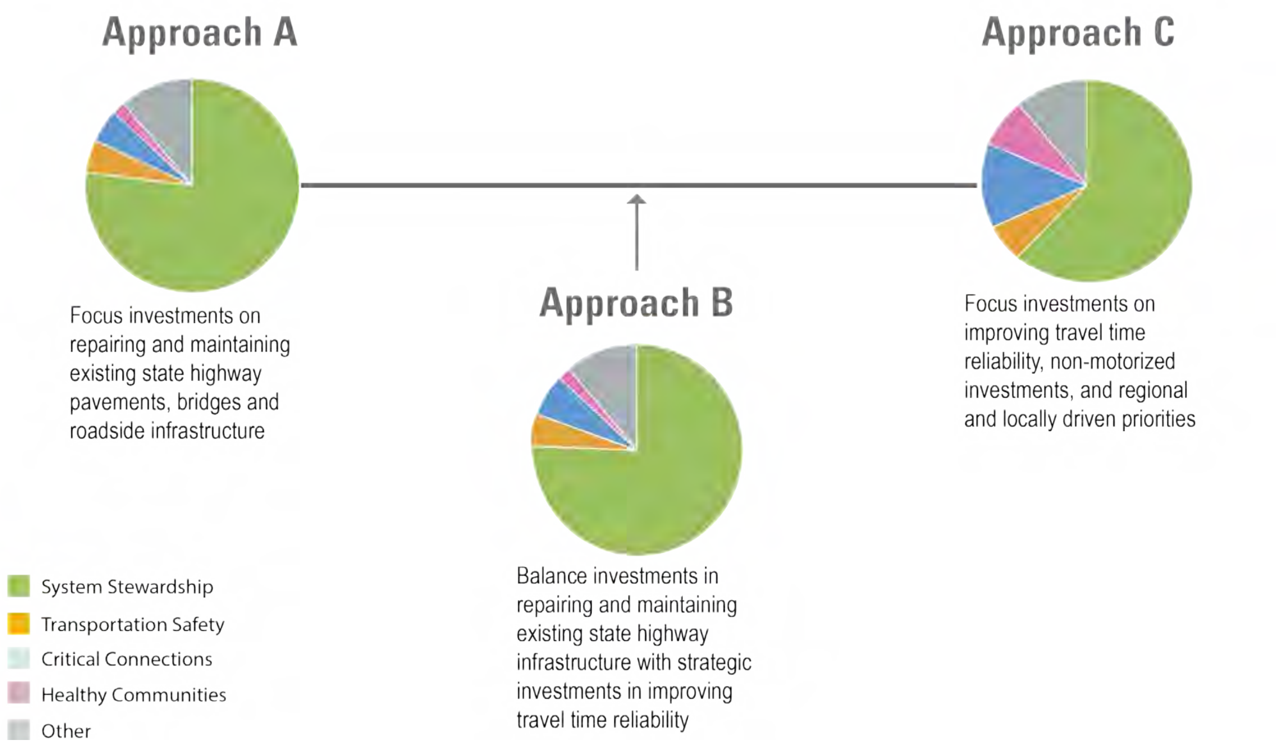
- Give asset management priority to infrastructure on identified priority networks
- Maximize the useful life of transportation assets while considering system performance, costs and impacts to the state's economy, environment and quality of life
- Incorporate asset management principles into capital, 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), which is a 20-year fiscally constrained plan. MnSHIP analyzes and tracks the impact of recent capital investments, identifies capital needs, establishes statewide priorities for projected revenue, and identifies strategies that ensure that MnDOT resources are used efficiently and effectively. The 2017 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

Figure 2-3: Investment Approaches Developed for Scenario Planning



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.

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.

These risks were used as the guiding focus in the development of the final MnSHIP investment strategies discussed in Chapter 8: Financial Plan and Investment Strategies.

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 ten 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 ten 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 to focus on 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 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 MnSHIP 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. Figure 2-4 summarizes the specific strategies that MnDOT adopted as a part of the MnSHIP development process to better manage performance in various capital program areas over the next 20 years. The TAMP focuses specifically on the strategies within the System Stewardship objective area category.

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

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

INVESTMENT CATEGORY	SYSTEM INVESTMENT STRATEGY
Transportation Safety - Traveler Safety	• Invest in high priority, lower cost proactive projects • Reactively install lighting at sustained crash locations
Critical Connections - Twin Cities Mobility	• Focus on investments that provide reliable congestion-free options on Twin Cities metro area corridors • Focus on low cost spot mobility projects that provide safety benefits and reduce delays
Critical Connections - Greater Minnesota Mobility	• Focus investment to improve travel time reliability through operational improvements such as upgraded traffic signals, ITS, turn lanes and passing lanes
Critical Connections - Freight	• System investment strategies for the Freight Investment category will be explored in the upcoming Freight Investment Plan
Critical Connections - Bicycle Infrastructure	• Focus 70 percent of bicycle investments in urban areas and 30 percent of investments in rural areas • Add to existing bridge and pavement projects to improve safety and connectivity of the state bikeway system
Critical Connections - Accessible Pedestrian Infrastructure	• Focus more investment in sidewalk, curb ramp and accessible pedestrian signal projects • Make other pedestrian improvements via complete streets and complete gaps in the network
Healthy Communities - Regional and Community Improvement Priorities	• Invest in economic development driven projects through the Transportation Economic Development program • Expand partnerships with local agencies/communities that leverage funds to complete larger projects
Project Delivery	• Make investments in right-of-way, consultant services, supplemental agreements/cost overruns and construction incentives to support the delivery of projects in other categories
Small Programs	• Ensure system resiliency to respond to unforeseen issues, one-time needs or changes in policy/funding

Existing Asset Management Programming Framework

Once investment levels are established, 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 developing pavement and bridge systems.

MnDOT manages pavement condition data through its Highway Pavement Management Application (HPMA) software. MnDOT uses HPMA to develop funding scenarios based on pavement treatment decision trees and performance prediction models to optimize the combination of preservation and rehabilitation activities and achieve the best conditions possible.

The Bridge Replacement and Improvement Management (BRIM) system contains an improvement module, expert review module, deterioration model and risk-assessment to prioritize bridge investments. It generates a bridge planning index score for each bridge in the state. Each bridge's score is based on risk factors (e.g. fracture criticality, substandard vertical clearance) and importance factors (e.g. traffic volume, detour length). This results in a bridge program that performs the right fix at the right time to reduce life cycle costs.

Finally, MnDOT uses numerous programs and spreadsheets, in addition to its employee timesheet system, to track asset related information and resource expenditure. These methodologies are in the midst of being consolidated into the Transportation Asset Management System (TAMS). This system went live in 2016 for traffic signals, lighting, and ITS. In 2018, hydraulic infrastructure and traffic barriers were added. Additional assets will continue to be added to the system.

Planned and programmed projects are based on recommendations from the management systems and input from MnDOT district personnel. 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 which represent MnDOT's planned projects
- Years 1-4, called the State Transportation Improvement Program, which represent projects MnDOT selected for funding and committed to delivering

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

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 of granularity 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 which directly relates work needs to asset conditions.

MnDOT also seeks to minimize the life cycle costs of owning its assets. Tables 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 which can be done with internal staff, which yield a high return on investment in terms of asset life (MnDOT’s pavement crack sealing efforts for example may yield a return on investment of over 10 to 1). This knowledge has encouraged field staff to prioritize this type of effort. At this time, 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 personnel and field maintenance management personnel. As MnDOT works to create a formal asset management policy, a culture of collaboration and integration is supported by efforts such as this.

MnDOT has also invested heavily in an asset management office whose functions include 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.

MnDOT is also implementing an Enterprise Asset Management (EAM) system called a Transportation Asset Management System (TAMS) to replace and consolidate the management of asset 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 management to field work management will all benefit from consistent and available data.

Chapter 3

ASSET MANAGEMENT PERFORMANCE MEASURES AND TARGETS

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ASSET MANAGEMENT PERFORMANCE MEASURES AND TARGETS

Overview

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

Existing Performance Measures and Targets

MnDOT's performance-based approach to asset management relies on performance measures to assess system performance, identify needs and develop investment priorities. Historically, these measures have included state highway ride quality and bridge condition. Additional performance measures, 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. Figure 3-1 lists MnDOT's performance measures as of the 2017 adoption of the State Highway Investment Plan (MnSHIP) by asset category. Short descriptions of each measure's rating scale and criteria are also included, along with MnSHIP targets (where applicable). Targets, both federally required targets and state imposed targets, 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

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 Condition Rating (SCR) and a Ride Quality Index (RQI), the latter of which defines whether a road is in good, fair or poor condition. A Pavement Quality Index (PQI), 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. Information regarding pavement condition on the National Highway System, regardless of ownership, is reported by MnDOT to the Federal Highway Administration each year.

Most bridges are inspected on two-year intervals and results are reported to the FHWA. Bridge inspections assess the condition of the decks, superstructures, substructures and large culverts using a standardized national survey procedure. Inspection results are used to determine which bridges are in good, satisfactory, fair or poor structural condition. Bridges in good 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 is 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.

Inspections of other assets are typically performed less frequently. However, they all use numeric rating scales. The advantage of the numeric classification system is a quantifiable rating which can be used to prioritize repair and/or maintenance. For highway culverts, the Transportation Asset Management System (TAMS) - HydInfra is used to manage the inventory as well as inspections and maintenance activities. During inspections, a condition rating is assigned to each culvert. The ratings range from 1 to 4, with 1 representing a feature in like new condition and 4 representing a feature in very poor condition with serious deterioration. 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.

Deep storm water tunnels are visually inspected approximately once every five years. Tunnel ratings include a numeric value (1, 2, 3, 4 or 5) based on the type of observed feature or defect (ranging from 1 being minor defect to 5 being most significant defect). Overhead sign structures have a standardized inspection manual recommending a five-year inspection schedule. A rating system of 0-9 is used, with 9 being excellent and 0 being a failed asset (no structures are in condition 0). An inspection manual for high-mast light tower structures has been developed and revised over time, using a 1-5 scale for individual elements with 1 being good condition and 5 being critical condition. Recently, a 0-9 overall structure rating was added with 0 as failed condition and 9 as excellent condition.

Figure 3-1: MnDOT 2017 Performance Measures by Asset Type

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 (RQI), 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)
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%

Notes: MnDOT uses multiple measures to evaluate the effectiveness of its pavement and bridge management activities. The measures listed here are those used to calculate MnDOT's performance-based investment needs. For a more comprehensive listing of MnDOT's pavement performance measures, see the *2017 Pavement Condition Annual Report*. Additional bridge measures can be found in MnDOT's *Annual Transportation Performance Report*.

The targets in Figure 3-1 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. More recently, MnDOT has established performance targets that it determines to be an acceptable risk. 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.

FEDERAL PERFORMANCE MEASURES AND TARGETS

As part of MAP-21, the Federal Highway Administration 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 3-2.

MnDOT has utilized 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 utilized existing long-term performance goals and planned projects to identify short-term proposed targets. Representatives from these workgroups met with MPOs on two occasions: 1) to provide information on the measure and MPO data and 2) to 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. Approximately one percent of the NHS is not owned by MnDOT - the MPOs approval will be on behalf of those segments. This process is still ongoing and will be finalized prior to the completion of the final TAMP.

Figure 3-2: Federal Performance Measures and Targets

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	FEDERAL TARGET
Pavements	Share of Interstate and non-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	TBD
Bridges	Share of NHS bridge deck area in good or poor condition	Measure is based on NBI condition ratings	TBD

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 set at 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. Since these targets are not yet set and they do not influence MnDOT decision making, the 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 of correction in the form of new spending priorities or a revised strategy.

Figure 3-3 summarizes the key characteristics of state targets, federal targets and expected outcomes, as explained above.

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

TERM	MEANING	USE	HOW IS IT ESTABLISHED?	HOW OFTEN IS IT USED?
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	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

Chapter 7 and Chapter 8 provide an expanded description of targets and expected outcomes for each of the asset categories covered in this TAMP.

Chapter 4

ASSET INVENTORY AND CONDITION

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ASSET INVENTORY AND CONDITION

Overview

Minnesota's state highway system includes 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 eight 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.

Collectively, the replacement value of all assets in this TAMP is roughly $41 billion as shown in Figure 4-1. In addition to roadways and bridges, MnDOT is responsible for maintaining many other transportation assets as shown in Figure 4-2. MnDOT has a direct ownership role in hydraulic infrastructure, roadside asset and traffic infrastructure within the right of way. For the majority of the multimodal assets, MnDOT manages grants 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: Inventory and Replacement Value Summary

STATE HIGHWAY SYSTEM ASSETS	UNIT/ COUNT	CURRENT REPLACEMENT VALUE
Pavements Roadway Miles	14,331	$29.4 billion
Bridges	4,801	$14.6 billion
Highway Culverts	40,687	$1.6 billion
Deep Stormwater Tunnels	8	$372 million
Overhead Sign Structures	1,858	$175 million
High-Mast Light Towers	478	$19 million
Noise Walls	434	$374 million
Signals and Lighting (Signal systems and pole mounted lighting)	28,566	$550 million
Pedestrian Infrastructure (Curb ramps and pedestrian bridges)	21,273	$279 million*
Buildings	875	$1.2 billion
Intelligent Transportation Systems	14,310	$151 million
Total	N/A	$40.6 billion

*Includes all pedestrian infrastructure

Figure 4-2: Examples of Additional Assets Managed by MnDOT

HYDRAULIC INFRASTRUCTURE

- Culverts
- Stormwater Collection and Treatment Systems
- Deep Stormwater Tunnels

TRAFFIC INFRASTRUCTURE

- Intelligent Transportation Systems
- Sensor Systems
- Traffic Signals
- Sign Structures
- Sign Panels

ROADSIDE ASSETS

- Pavement Marking, Striping
- Curb and Gutter
- Guardrails
- Fence, Barriers, Impact Attenuators
- Noise Walls
- Slopes, Embankments, Retaining Walls
- Rest Areas
- Weigh Stations
- Lighting Structures

MULTIMODAL ASSETS

- Curb Ramps, Sidewalks, Accessible Pedestrian Signals
- Bicycle and Pedestrian Facilities
- Transit (Bus and Rail)
- Freight
- Airports
- Ports and Waterways

Factors Influencing Asset Condition and Performance

The advanced age of Minnesota's state highway assets is one of the primary challenges facing MnDOT today. Figure 4-3 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

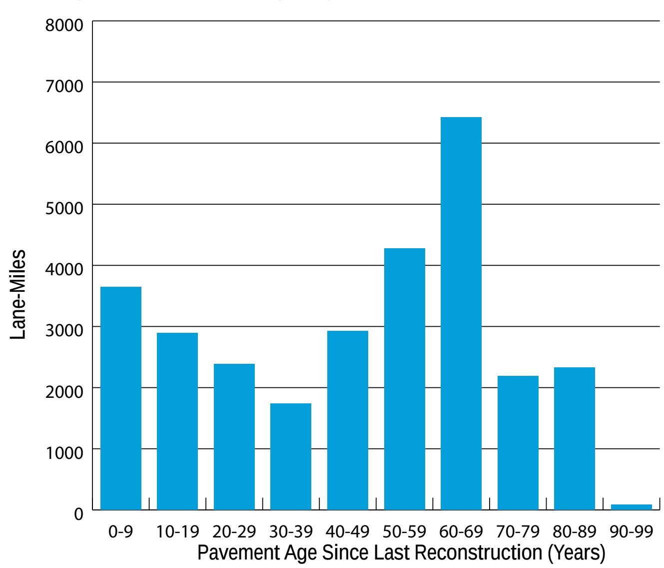
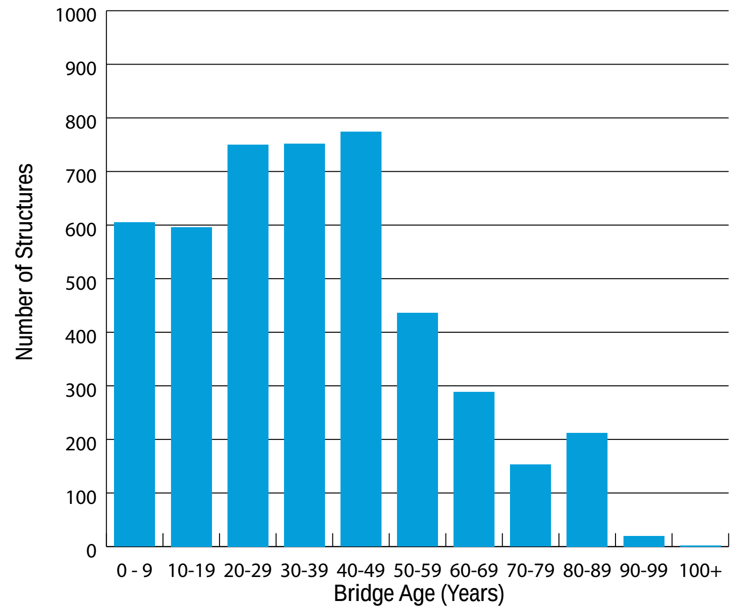


Figure 4-4: Age Profile of State Highway Bridges



damage and highlighted the need to better understand flooding impacts on asset condition. MnDOT recently 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 in 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	• Usage 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 following selected asset categories: pavements, bridges, 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.

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. MnDOT is afforded by the TAMP development 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 38, 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.

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.

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

PAVEMENTS

Pavements are a critical part of MnDOT's transportation network, providing mobility and access to a wide range of users. MnDOT's system consists of two types of pavements: flexible and rigid. Flexible pavements are often referred to as bituminous or black top, while rigid is commonly referred to as concrete. The state system consists of Interstates, 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	CURRENT 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

Notes: Interstate and Other NHS do not include locally-owned NHS roadways (78 roadway miles); MnDOT has initiated a process to collect locally-owned NHS pavement and bridge data (i.e. material type, AADT, construction and treatment history, design details), and will be developing a solicitation process that aligns with the state-owned NHS investment direction; current replacement value based on $1 million per lane-mile

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

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

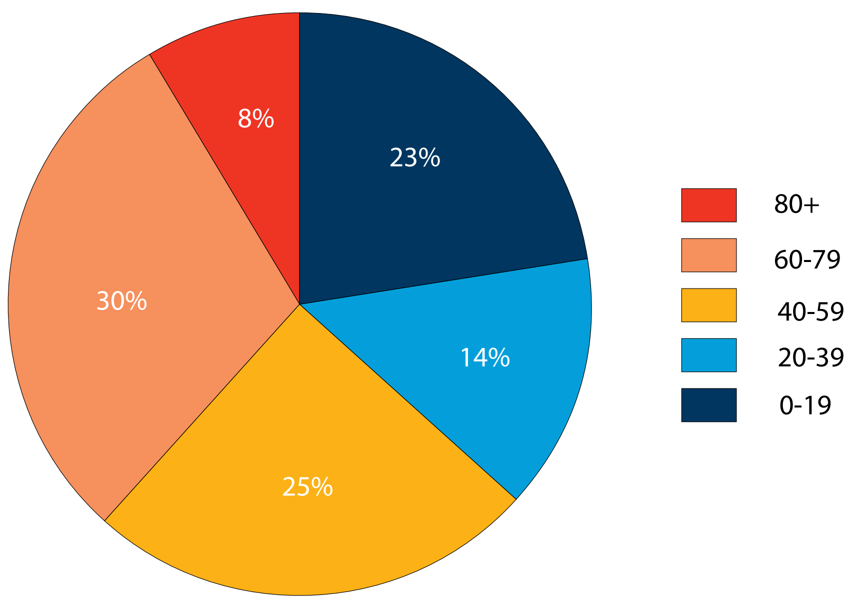
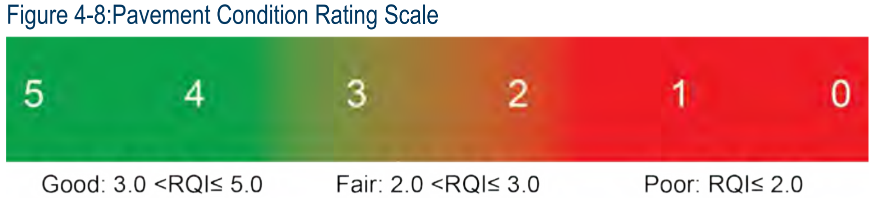


Figure 4-8:Pavement Condition Rating Scale



Data Collection, Management, and Reporting Practices

Data Collection:

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

Data Management:

- Highway Pavement Management Application (HPMA) used to 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 (HPMS)

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%	NA
Other NHS	1.7%	≤ 4%	NA
Non-NHS	4.4%	≤ 10%	NA
TOTAL	NA	NA	NA

Note: Interstate and Other NHS do not include locally-owned NHS roadways (78 roadway miles)

Federal Pavement Performance Measures and Targets

The federal pavement performance measures 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.

Figure 4-10: Pavement Current Condition, Targets, and Investment to Achieve Targets in 2027 Based on Federal Performance Measures

SYSTEM	2017 CONDITION (% GOOD)	2017 CONDITION (% POOR)	TARGETS (% GOOD)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Interstate	60.0%	1.1%	TBD	TBD	TBD
Other NHS	53.3%	1.7%	TBD	TBD	TBD
TOTAL	NA	NA	NA	NA	TBD

BRIDGES (INCLUDING LARGE CULVERTS)

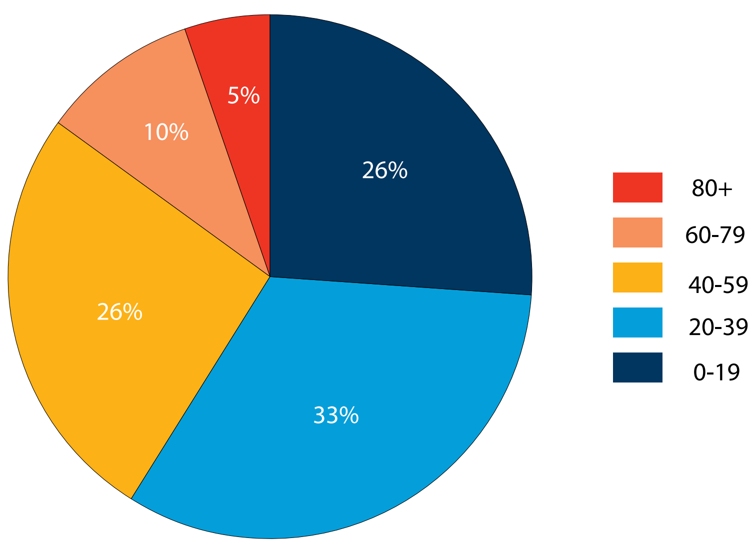
Bridges are large, complex and expensive assets that are custom-designed and built to satisfy a wide variety of requirements. Large culverts 10 feet and greater are also included in the bridge inventory. MnDOT's bridge inventory includes all bridge structures ten feet and greater. There are currently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

Figure 4-11: Bridge Inventory and Replacement Value

SYSTEM / FUNCTIONAL CLASSIFICATION	BRIDGE COUNT	BRIDGE DECK AREA (SQ. FT.)	BRIDGE CURRENT REPLACEMENT VALUE	BRIDGE CULVERTS COUNT	BRIDGE CULVERTS CURRENT REPLACEMENT COST
NHS	1,621	31,444,986	$8.8 billion	745	$470 million
Non-NHS	1,377	18,504,855	$5 billion	1,058	$329 million
TOTAL (State Highway)	2,998	49,949,841	$13.8 billion	1803	$799 million

Notes: NHS do not include locally-owned NHS bridges (23); replacement values range from $50/sq. ft. to $820/sq. ft. depending on bridge type, size and complexity; MnDOT has initiated a process to collect locally-owned NHS pavement and bridge data (i.e. material type, AADT, construction and treatment history, design details), and will be developing a solicitation process that aligns with the state-owned NHS investment direction

Figure 4-12: Bridge Age Profile (by deck area in sq. ft.)



Data Collection, Management, and Reporting Practices

Data Collection:

- Data collection based on National Bridge Inspection Standards (NBIS), 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 inspections with some centralized management and Quality Assurance/Quality Control of data collected

Data Management:

- Structure Information Management System (SIMS) used to enter, submit and manage inspection data
- Bridge Replacement and Improvement Management (BRIM) tools used to analyze data

Data Reporting:

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

Figure 4-13: Bridge Condition Rating Scale (Based on NBIS Rating Scale)

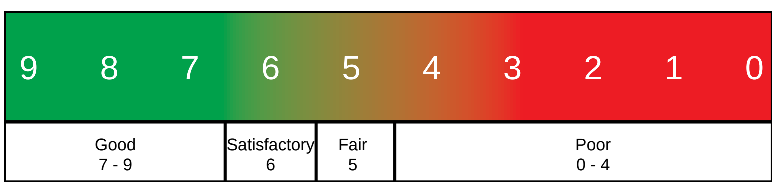


Figure 4-14:Bridge Current Condition, Targets, and Investment to Achieve Targets in 2027 Based on State Performance Measures

SYSTEM	2017 CONDITION (% POOR)	TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
NHS	4.7%	≤ 2%	$1.1 billion
Non-NHS	2.1%	≤ 8%	$430 million
TOTAL	4.3%	NA	$1.5 billion

Note: NHS does not include locally-owned NHS bridges (23)

Federal Bridge Performance Measures and Targets

The federal performance bridge measures are based on NBI condition ratings.

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

SYSTEM	2017 CONDITION (% GOOD)	2017 CONDITION (% POOR)	TARGET (% GOOD)	TARGET (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
NHS	47.4%	1.5%	TBD	TBD	TBD
TOTAL	NA	NA	NA	NA	TBD

HYDRAULIC INFRASTRUCTURE (HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS)

Hydraulic infrastructure, including centerline highway culverts (diameter less than 10 feet) and deep storm water 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.

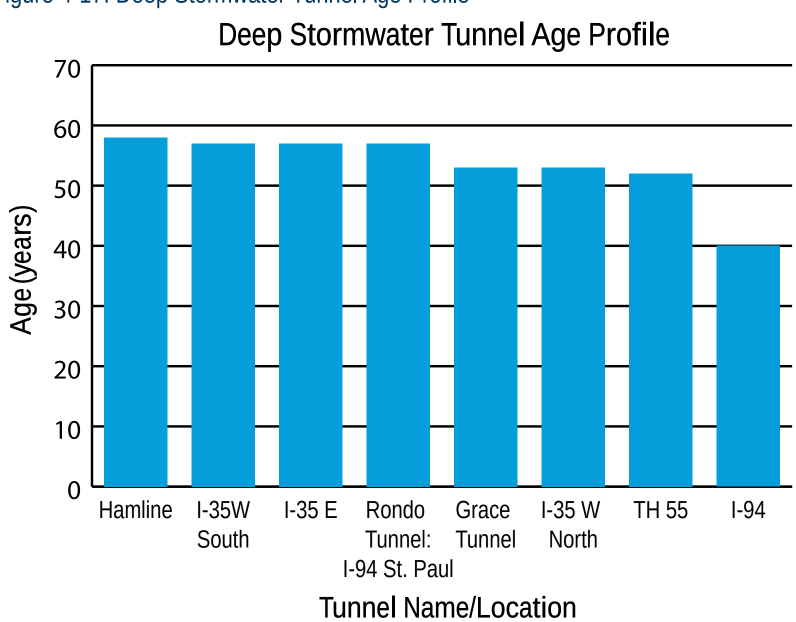
Not all hydraulic infrastructure was included in the TAMP. Hydraulic infrastructure including median and driveway/entrance culverts, interconnected storm sewer system piping and their associated catch basins, manholes and drop inlets, stormwater treatment systems such as ponds, infiltration/filtration basins and structural pollution control devices are a part of the Transportation Asset Management System (TAMS) HydInfra database, 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 4-16: Hydraulic Infrastructure Inventory and Replacement Value

ASSET TYPE	COUNT / UNIT	CURRENT 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

Figure 4-17: Deep Stormwater Tunnel Age Profile



Data Collection, Management, and Reporting Practices

Data Collection:

- Condition inspections performed in-house or through contract
- Data collection frequency varies: 1 to 6 years for culverts, 2 to 5 years for deep stormwater tunnels
- Culverts managed by MnDOT districts: Maintenance and/or Hydraulics / Water Resources Engineering (WRE), Tunnels managed by Metro District WRE
- Deep storm water tunnel conditions are documented using the Pipeline Assessment and Certification Program developed by National Association of Sewer Service Companies
- Utilizing 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 4-18: Highway Culverts Condition Rating Scale

1	2	3	4	0
Excellent 1	Fair 2	Poor 3	Severe 4	Not able to rate, not visible 0

Figure 4-19: Deep Stormwater Condition Rating Scale

1	2	3	4	5
Minor Defects 1	Minor to Moderate Defects 2	Moderate Defects 3	Significant Defects 4	Most Significant Defects 5

Figure 4-20: 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% (Conditions 3 + 4)	≤ 10% (Conditions 3 + 4)	$290 million
Deep Stormwater Tunnels	19% (Conditions 4 + 5)	≤ 10% (Conditions 4 + 5)	$4.5 million

OVERHEAD SIGN STRUCTURES

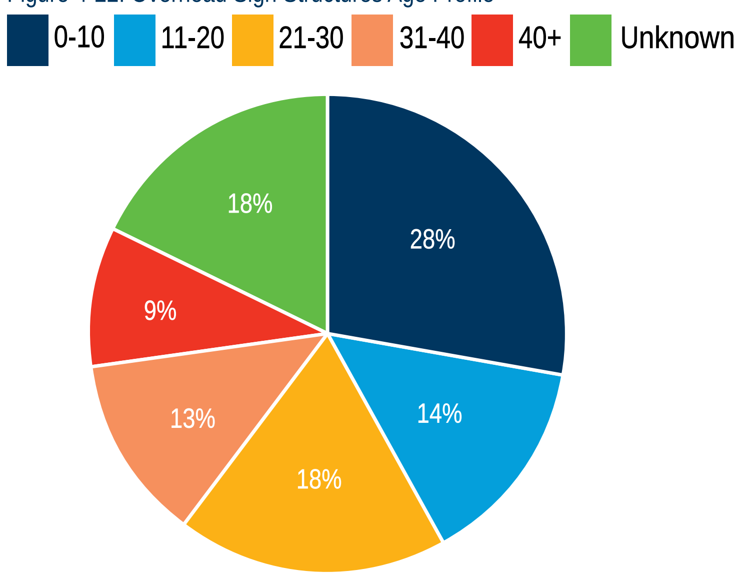
Overhead sign structures include various types of span and cantilever stand alone structures, designed to support signs requiring vertical clearance for vehicles to pass underneath. This also includes sign structures outside of MnDOT Right Of Way that carry sign panels directing motorists to MnDOT roadways. 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 4-21: Overhead Sign Structure Inventory and Replacement Value

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

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

Figure 4-22: Overhead Sign Structures Age Profile



Data Collection, Management, and Reporting Practices

Data Collection:

- Condition inspections performed in-house or via contract
- Utilizing standard specification for As-Builts to track new construction projects
- Data collection typically on a five-year cycle
- 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 in the near future

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 4-23: Overhead Sign Structure Condition Rating Scale

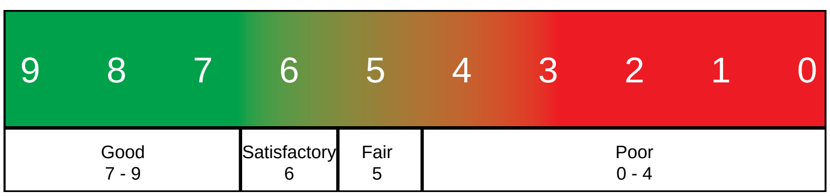


Figure 4-24: Overhead Sign Structures Condition, Targets, and Investment to Achieve Targets in 2027

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

HIGH-MAST LIGHT TOWERS

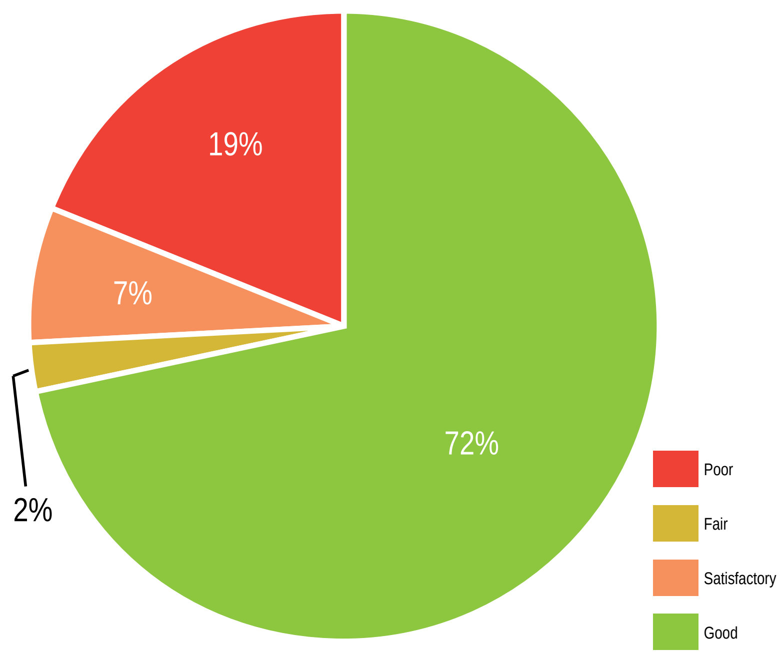
High-mast light tower structures are tall poles, 100-140 feet in height, which support 3-6 large lamps. The analysis performed in this TAMP accounts only for structural condition; other functional and operational requirements (e.g. luminaire replacement) are not considered.

Figure 4-25: High-Mast Light Tower Structures Inventory and Replacement Value

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

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

Figure 4-26: High-Mast Light Tower Structure Condition Profile



Data Collection, Management, and Reporting Practices

Data Collection:

- Condition inspections performed in-house or via contract
- Utilizing 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 Structures Condition Rating Scale

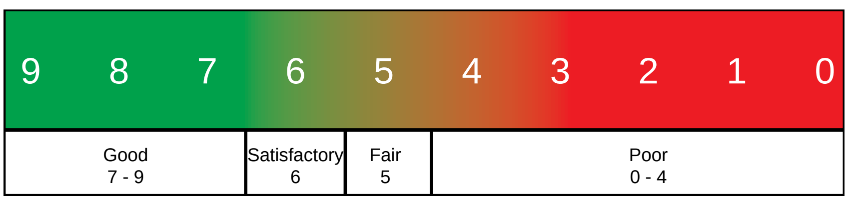


Figure 4-28: High-Mast Light Tower Structures Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	DRAFT TARGET (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
High-Mast Light Tower Structures	18%	≤ 6%	N/A

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% are located in the 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

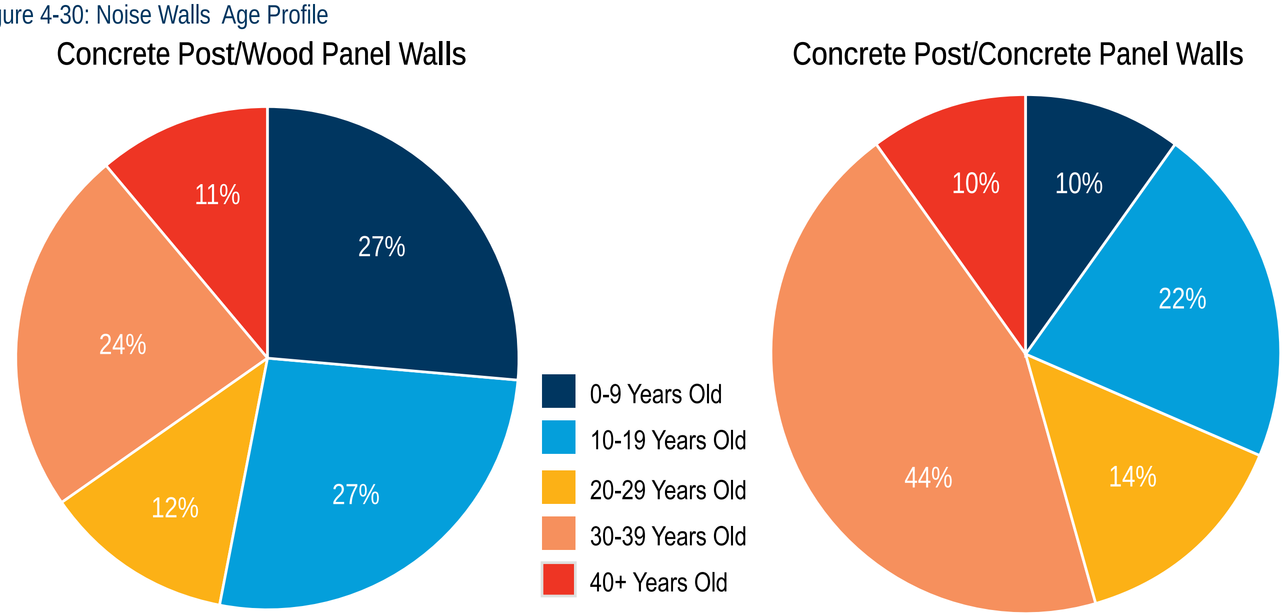
WALL TYPE	COUNT	WALL AREA (SQ. FT.)	CURRENT REPLACEMENT VALUE
Wood*	364	10,080,028	$312 million
Concrete**	70	1,431,654	$62 million
TOTAL	434	11,511,682	$374 million

Notes: 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:

- Utilizing standard specification for As-Builts to track new construction projects
- Condition collected once in Metro District in 2012
- Frequency of data collection varies by district

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 Walls Condition Rating Scale

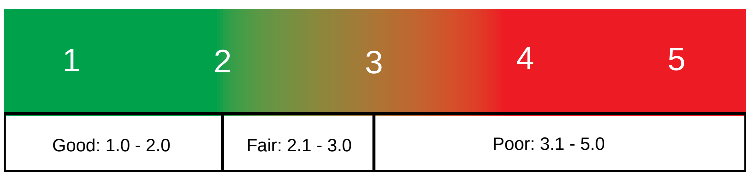


Figure 4-32: Noise Walls Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	DRAFT TARGET (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Noise Walls	11%	≤ 2%	$59 Million

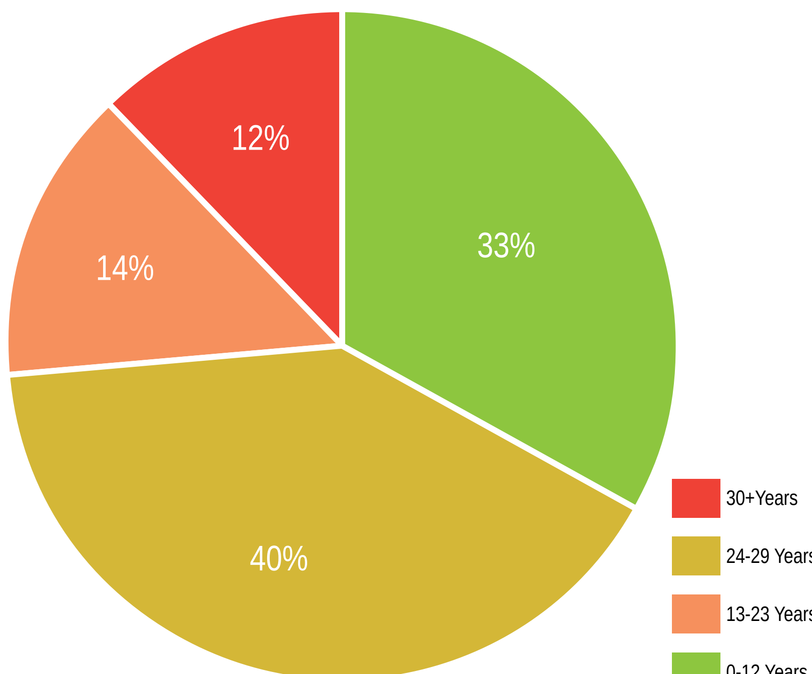
SIGNALS AND LIGHTING

Traffic signals and lighting structures are important assets on the state highway system. MnDOT currently owns approximately 1,300 traffic signals and over 27,000 lighting structures. These assets are managed by district offices and the Office of Traffic, Safety and Technology, and maintained by the MnDOT Electrical Services 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	CURRENT REPLACEMENT VALUE
Traffic Signal Systems	1,295	$324 million
Lighting	27,147	$217 million
TOTAL	28,566	$549.6 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
- Utilizing standard specification for As-Builts to track new construction projects
- Greater MN districts complete one-time 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

Data Reporting:

- No standard practice or required reports

Figure 4-35: Signals and Lighting Condition Rating Scale

Good: 0-12 years	Fair: 13-23 years	Poor: 24-29 years	Very Poor: 30+ years

Figure 4-36: Signals and Lighting Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	DRAFT TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Traffic Signal Systems	29%	≤ 6%	$206 million
Lighting	38%	≤ 6%	$144 million

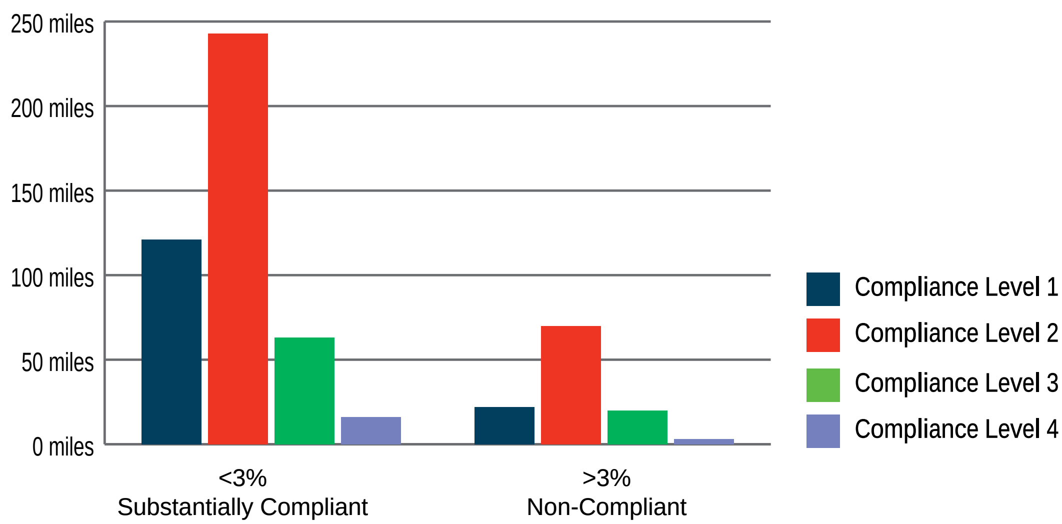
PEDESTRIAN INFRASTRUCTURE

Pedestrian assets include infrastructure that aid in making traveling along side or across roadways accessible to all pedestrians. These include curb ramps, sidewalks, driveways with sidewalks and pedestrian bridges. MnDOT currently owns over 563 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 modal plan.

Figure 4-37: Pedestrian Inventory and Replacement Value

ASSET TYPE	COUNT/AREA	COST PER UNIT	CURRENT REPLACEMENT VALUE
Curb Ramps	21,175	$3,000	$64 million
Sidewalk	9,151,206 sq. ft.	$9/ sq. ft.	$82 million
Driveway with Sidewalk	3,884 (residential) 4,860 (commercial)	$3,000 (residential) $5,000 (commercial)	$26 million
Pedestrian Bridge	98	$1 million/ bridge	$98 million
TOTAL	N/A	N/A	$279 million

Figure 4-38: ADA Compliance of Sidewalks



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 (APS)

Figure 4-39: Sidewalks and Ramps Condition and Compliance Rating Scale

0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Good: 0.0"-0.1"	Fair: 0.11"-0.24"	Poor: 0.25"-0.49"		Very Poor: 0.5"+						

Figure 4-40: Pedestrian Infrastructure Compliance, Targets, and Investment to Achieve Targets in 2027

ASSET TYPE	2010-2013 COMPLIANCE (% NON-ADA COMPLIANT)	DRAFT TARGETS (% NON-ADA COMPLIANT)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Curb Ramps	73%	≤ 6%	$140 million
Sidewalk*	33%	≤ 5%	$110.8 million
Driveway with Sidewalk	N/A	N/A	N/A
Pedestrian Bridge	N/A	N/A	N/A

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

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. This TAMP effort is concurrent with a Building Services Facilities Condition Assessment (FCA) which will collect condition data on all MnDOT-owned buildings.

Figure 4-41: Building Inventory and Replacement Value

BUILDINGS TYPE	COUNT	CURRENT 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 or partially heated)	48	$34.8 million
Storage sheds (unheated)	306	$90.6 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	875	$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.
*MnDOT's Central Office is not included as it is owned by the Department of Administrations.
**Metro District's offices at Water's Edge is 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 3 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 4-42: Building Condition Rating Scale

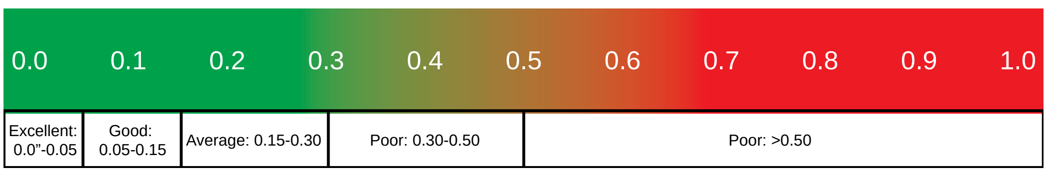


Figure 4-43: Building Condition, Targets, and Investment to Achieve Targets in 2027

SYSTEM	2017 CONDITION (% POOR)	DRAFT TARGETS (% POOR)	INVESTMENT REQUIRED TO ACHIEVE TARGETS
Rest Areas and Weigh Stations/ Scales	12% (Rest Areas) 0% (Weigh Stations/Scales)	≤ 8% (Rest Areas) ≤ 14% (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 or partially heated) • 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)	≤ 8% (Class 2 and 3 truck stations) ≤ 3% (Class 1 truck stations) ≤ 15% (Salt sheds) ≤ 10% (Heated storage sheds) ≤ 15% (Unheated storage sheds) ≤ 10% (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 ten years.

INTELLIGENT TRANSPORTATION SYSTEMS

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 (RWIS) and other information and communication systems. All of these assets are relatively new – installed in 1998 or after – and currently do not have clear life cycle cost analysis structures in place. MnDOT's ITS unit performs research, demonstrations and operational test activities focusing on technology-based transportation solutions.

Figure 4-44: ITS Inventory and Replacement Value

ITS ASSET TYPE	COUNT	CURRENT REPLACEMENT VALUE
Fiber communication network	703 miles	$24.6 million
Fiber network shelters	71	$7.8 million
Traffic Management System (TMS) 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) (En/Decoding devices being phased out with switch from analog to IP traffic cameras)	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 (RICWS)	54	$8.1 million
Road Weather Information Systems Sites (RWIS)	98	$5.9 million
Automatic Traffic Recorders (ATR)	71	$3.7 million
Weigh-In-Motion System Sites (WIM)	24	$5.2 million
Road Closure	101	$1.0 million
TOTAL	N/A	$150.7 million

Data Collection, Management, and Reporting Practices

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 yearly to every five years

Data Management:

- All ITS assets are managed in TAMS

Data Reporting:

- No official reporting of ITS data

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

SYSTEM	2017 CONDITION (% POOR)	DRAFT TARGETS (% POOR)	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
RICWS	0%	≤ 6%	$6.1 million
RWIS	0%	≤ 2%	$8.0 million
ATR and WIM	No inspection criteria	≤ 10%	$11.1 million
Road Closure	0%	≤ 10%	$0.8 million
TOTAL	N/A	N/A	$108.2 million

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. Most recently, risk assessments have been formally incorporated into the Minnesota 20-year State Highway Investment Plan (MnSHIP). This strong history with risk prompted MnDOT to take a somewhat unique approach to the Risk Management Analysis section of the TAMP. Because risk management is already integrated into most agency planning and management practices, it was recognized that focusing on "global" risks (e.g. natural events, operational hazards, aging assets) would be less beneficial than assessing and developing mitigation strategies for "undermanaged" risks – opportunities that exist for MnDOT to further improve its asset management processes. 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 departments, 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
- Loss of 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 a known inventory of assets MnDOT owns and maintains
- Conducting routine inspections to continuously understand the condition of our assets
- Raising awareness of risks among staff and the public
- Adopting management strategies and techniques to avoid risks
- Prioritizing risk-prone assets for replacement
- Mitigating asset risks based on measurable characteristics that affect their resilience and exposure
- Working with partners and stakeholders on ways to reduce or to jointly manage risks through maintenance agreements, jurisdictional transfer or other management strategies

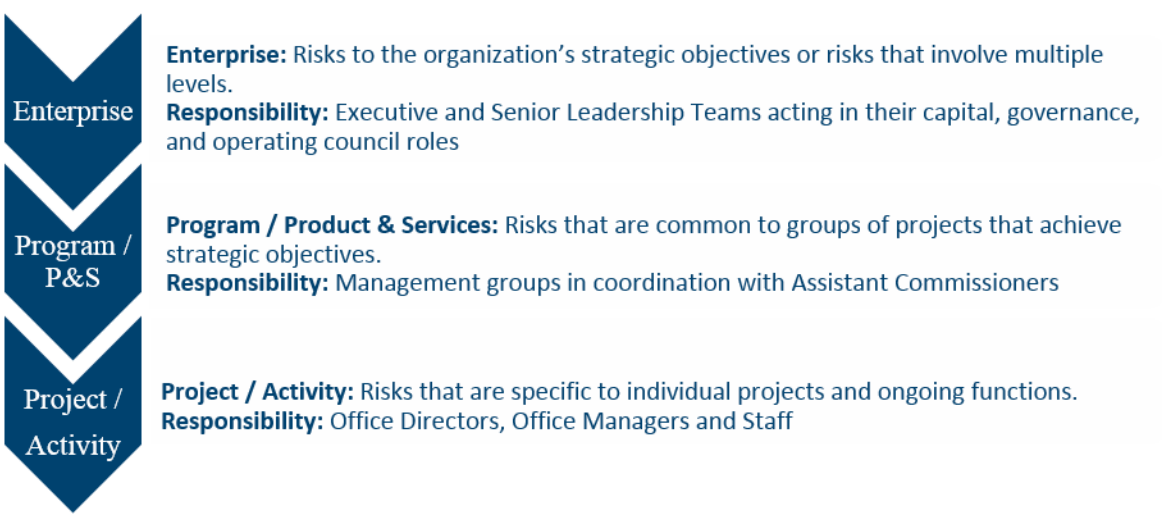
Risk at MnDOT

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 (ERM)

To help guide the transition to formal and universal consideration of risk, MnDOT has implemented an ERM framework. The framework – illustrated in Figure 5-2 – 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 allows you to identify 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 (MNSHIP)

Risk was a key factor considered during the 2017 MnSHIP process. 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 (SPP) and the District Risk Management Program (DRMP). By enhancing flexibility and collaboration with regional and local MnDOT staff, these programs help the agency effectively reallocate funding and address these changes. Further discussion of MnSHIP, the SPP and the DRMP is found in Chapter 8: Financial Plan and Investment Strategies.

Figure 5-3 displays the capital investment risks categories considered in MnSHIP and the degree to which each is mitigated via the strategies outlined in the plan.

Figure 5-3: Key Investment Risks

KEY INVESTMENT RISK	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

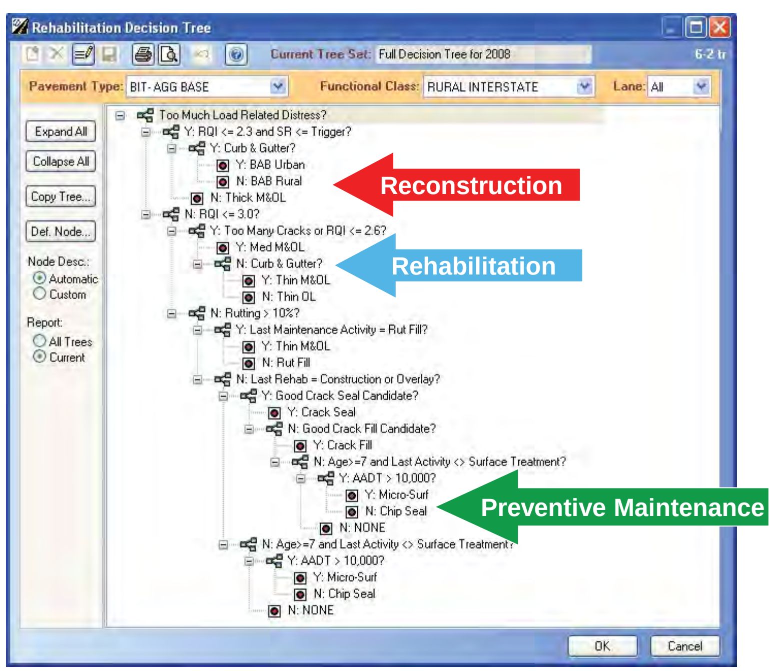
In addition to risk management of the capital program, MnDOT has also made great strides in assessing and reducing its risks for operations and maintenance. MnDOT has invested heavily to inventory its less prominent assets, such as ITS and lighting, in an effort to be holistic and comprehensive, including measuring condition and placement into 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.

HIGHWAY PAVEMENT MANAGEMENT APPLICATION (HPMA)

Decisions about pavement management at MnDOT are made with the help of HPMA, which uses pavement condition data to forecast needs and optimize the combination of preservation and rehabilitation activities, in order to most effectively mitigate risk and achieve the best conditions possible given funding constraints. The dynamic application allows for comparisons between a range of treatment option scenarios, from “minimum maintenance only” to “full reconstruction”. This process is explained further in Chapter 8: Financial Plan and Investment Strategies.

Risks associated with the application were evaluated and addressed as part of risk exercises and are identified in MnDOT’s ERM risk register. A conceptual model of HPMA is shown in Figure 5-4.

Figure 5-4: HPMA Decision Tree



BRIDGE REPLACEMENT AND IMPROVEMENT MANAGEMENT (BRIM) SYSTEM

BRIM is used by MnDOT to identify, classify, evaluate and plan for a variety of quantifiable risks that apply to highway bridges. Hazards analyzed in BRIM include:

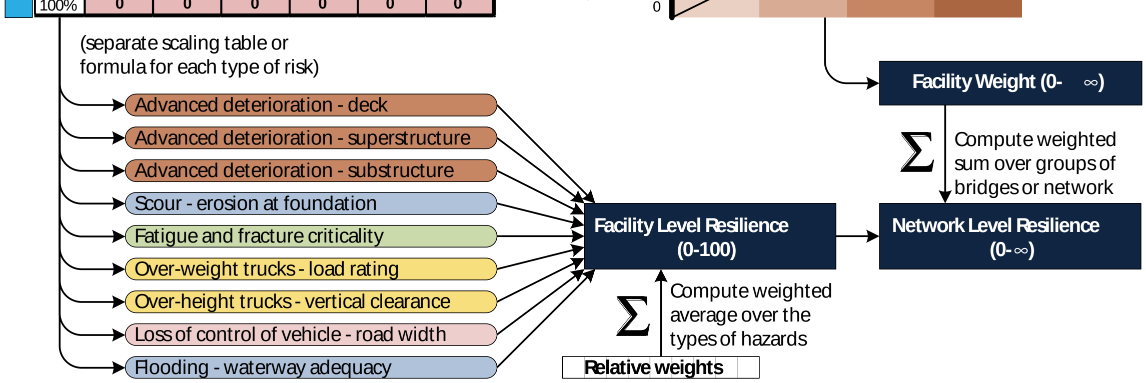
- Advanced deterioration of bridge decks, superstructures and substructures
- Scour of riverbeds around bridge foundations
- Fracture criticality (possibility of bridge instability due to failure of only one element)
- Fatigue cracking
- Overload
- Collisions with over-height vehicles

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

Figure 5-5: Example Bridge Programming Risk Assessment

Consequence to structure

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



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

RESEARCH PROJECTS

Finally, the concept of risk also factors heavily into several 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 recently completed a Flash Flood Vulnerability 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 severe 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 flash 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. Additionally, a slope vulnerability assessment is currently underway.

TAMP Risk Assessment

As detailed above, risk is an important part of MnDOT's practices. Nevertheless, the agency's approach to the risk section of the TAMP process began with a focus on "global" risks (e.g. natural events, operational hazards) and their effects on the asset, the public, and the agency. MnDOT engaged in an exercise to identify and prioritize strategic and business risks that could impact its ability to deliver the level of service expected by the public. Discussions were held with work groups of technical experts to describe and rate the major risks related to each asset category. Figure 5-6 summarizes the list of risks as identified by the asset work groups while Figure 5-7 illustrates MnDOT's risk rating scale. In consultation with agency risk experts, each work group developed a series of risk statements and risk ratings, described potential mitigation strategies for each risk and developed methods for estimating mitigation costs. This process was iterative, extending over three formal workshops, with opportunities between workshops to modify aspects of the product. Participants took advantage of the process to learn about the risks, assess the ability of existing information systems to quantify risks and costs, and reach consensus on priorities and approaches for future improvements.

Given MnDOT's previous efforts at incorporating risk throughout its planning and management, the risk identification and mitigation process also sparked a debate as to the merits of a more conventional risk approach. It was concluded that MnDOT's current practices were already mindful of many global risks, and that the agency (and the public it serves) would therefore benefit most if the risk mitigation strategies addressed in the TAMP emphasized "undermanaged

Figure 5-6: Risks Identified by Asset Work Groups

ASSET	RISKS
Pavement	• Unexpected short-term funding reductions does not allow MnDOT to manage to the lowest life cycle cost • *Not meeting public expectations for pavement quality/condition at the state/ district/local levels** • Inability to meet federal requirements • Significant reduction in funding over time • *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** • 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
Bridges	• *Unexpected funding reductions does not allow MnDOT to manage to the lowest life cycle cost** • *Premature deterioration of the asset** • Shortage of workforce • Catastrophic failure of the asset • Significant damage to the asset through man-made or natural events
Highway Culverts and Deep Stormwater Tunnels	• *Failure/collapse of tunnel/culvert** • *Flooding and deterioration due to lack of tunnel/culvert capacity** • Lack of culvert capacity, potentially resulting in adverse impacts to properties and roadway user safety • *Inability to manage culverts to lowest life cycle cost** • Difficulty to appropriately manage tunnels due to unexpected availability of funding • Inappropriately distributing funds or inconsistency in culvert investments • Significant damage to culverts through man-made events

*Undermanaged risks identified and prioritized in pilot TAMP

Figure 5-6: Risks Identified by Asset Work Groups

ASSET	RISKS
Overhead Sign Structures and High-Mast Light Towers	• Poor construction and/or installation • Inability to manage to lowest life cycle cost • Significant damage to asset through man-made events • Premature deterioration of the asset • Unforeseen changes in regulatory requirements, travel demands or technology • Shortage of workforce • Potential structural failure
Noise Walls	• Not repairing problems identified during inspection • Not managing noise walls to lowest life cycle • Not inspecting noise walls
Signals and Lighting	• Poor traffic signal timing • Poor construction and/or installation • Light pole failure or light inoperability
Buildings	• Inability to manage buildings appropriately/efficiently • Lack of dedicated capital and maintenance funding • Increasing maintenance equipment size, including tow plows • Temporary or permanent rest area closures
ITS	• System design, construction issues or system flaws (vulnerability) • Inadequate operations/maintenance funding and staff • Not identifying an appropriate responsible party for maintenance/operations • Ineffective (poor) vendor accessibility, communication or relationship • Technology shift/obsolescence • Extreme weather
Pedestrian Infrastructure	• Not meeting the needs of system users, including the disabled community • Not meeting federal compliance or the intent of ADA • Poor planning, design and/or construction • Failure to comply with Complete Streets Policy • Failure to address system gaps with future funding

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 pavement, bridge, culvert, deep stormwater tunnel, overhead sign structure and high-mast light tower structures was presented to the Steering Committee for prioritization. Since this process, risks were identified for additional assets. The asset-specific work groups, along with members of the TAMP Advisory Group and Asset Management Steering committee, will revisit risks from all assets to conduct a cross-asset risk workshop to be included in the final TAMP. Because less than one percent of the NHS is not owned by MnDOT, other owners of the NHS were not involved in the risk prioritization.

Figure 5-7: 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 5-8 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 workgroups prioritized mitigation strategies as part of the pilot project that was completed for pavement, bridge, highway culverts, deep stormwater tunnels and overhead sign structures. MnDOT plans to identify and prioritize mitigation strategies for additional assets, including noise walls, signals, lighting, ITS, buildings and pedestrian infrastructure to be included in the final asset management plan. Chapter 9: Implementation and Future Developments provides more detail for these priorities, including purposes, responsible parties, expected time frames and estimated implementation costs.

Figure 5-8: 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
- Highway Culverts: Improve methodology for monitoring highway culvert performance in TAMS
- Overhead Sign Structures and High-Mast Light Tower Structures: Continue to develop and adequately communicate construction specifications
- Overhead Sign Structures and High-Mast Light Tower Structures: Track in a Transportation Asset Management System (TAMS)

PRIORITY LEVEL 2: ADDRESS BASED ON ESTABLISHED PRIORITIES

- Pavements: Collect and evaluate performance data on ramps, auxiliary lanes and frontage road pavements for the highway system in the Twin Cities Metro Area
- 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 for overhead sign structures, as well as related inspection training programs and forms

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

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

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 1st, 1997 to the present. Best available data was extracted from Detailed Damage Inspection Reports (DDIR), the Program and Project Management System (PPMS), the Fiscal Management Information System (FMIS) and other project description documents or systems. Data was then mapped using Geographic Information System (GIS) 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.

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 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.

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

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.

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 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 1.3 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 preventative 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 preventative 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

- Future Maintenance Costs as a Percent of Initial Investment: the total future agency costs (including maintenance, rehabilitation and inspection, but not operations costs) as a fraction of the initial construction cost of the asset (This value represents the future cost commitment that MnDOT makes for every dollar spent on a capital project.)

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 (SMTP), which describes investments and interaction between transportation modes, and its Minnesota State Highway Investment Plan (MnSHIP), 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, and 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.

The key messages of MnSHIP are:

- MnDOT will make progress in all investment areas, but not all performance targets will be met. Pavement condition is expected to decline significantly.

- MnDOT will put most of its available revenues toward maintaining the existing transportation system, which is consistent with asset management principles and public and stakeholder input.

- MnDOT will apply multiple strategies to optimize resources and achieve multiple purposes through its planned investments.

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.

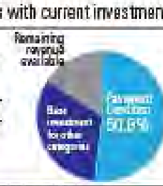
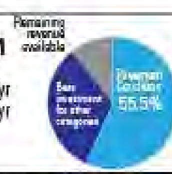
These performance levels represented, in broad terms, concepts such as:

- 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 (HPMA) and Bridge Replacement and Improvement Model (BRIM) systems. 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.

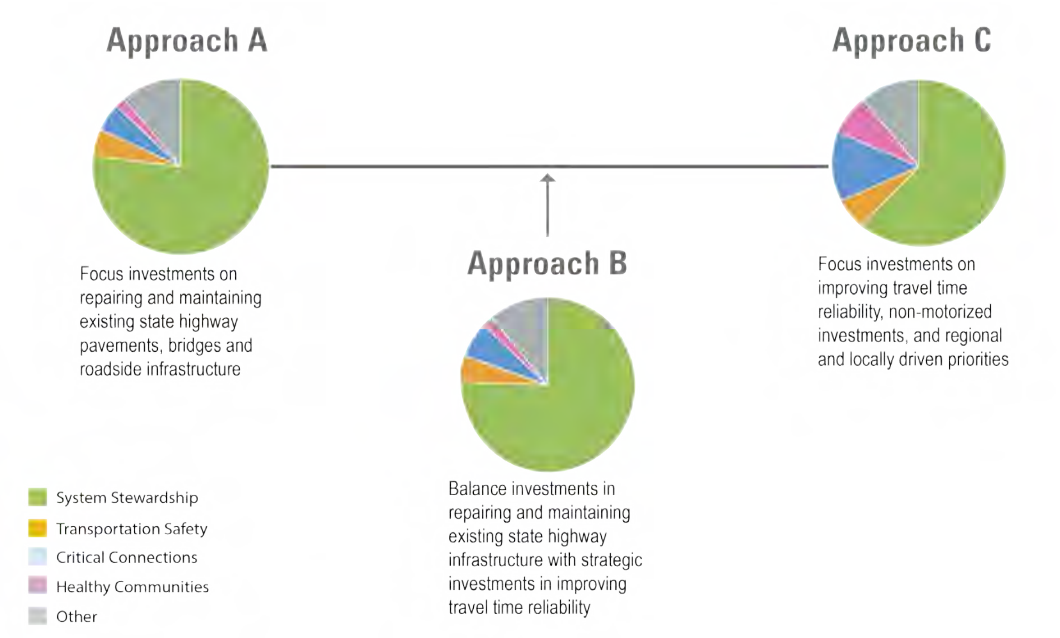
The following excerpts from MnSHIP present the results of the recent MnSHIP planning process.

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.

Rolling up the performance level scenarios for individual asset classes, MnDOT used the three approaches in Figure 6-2 to show how available funding could be divided among the investment categories over the next 20 years based on different priorities. This demonstrates a range of possible outcomes and risks.

Figure 6-2: Investment Approaches Developed for Scenario Planning



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 6-3 shows the distribution of expenditures through all years of the plan.

Figure 6-3: 20-Year Capital Highway Investment Direction

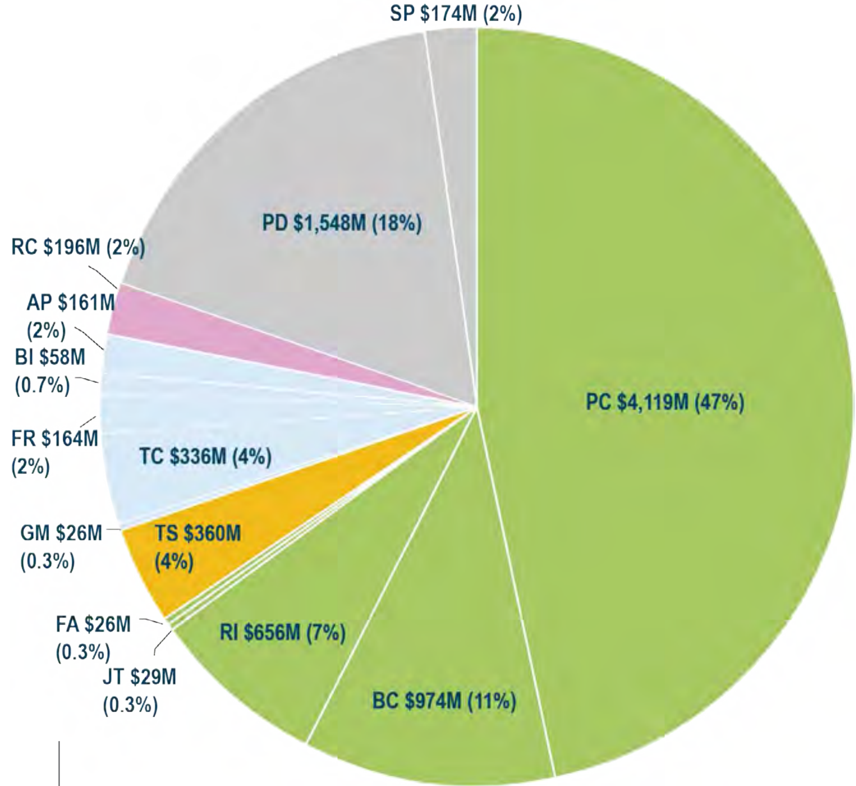


Figure 6-4: Investment Direction by Time Periods

INVESTMENT CATEGORIES	FY2018-2021	FY2022-2023	FY2024-2037
Pavement Condition	33.5%	47.3%	52.9%
Bridge Condition	15.6%	8.2%	9.7%
Roadside Infrastructure	8.7%	6.9%	7.7%
Jurisdictional Transfer	0.0%	0.5%	0.5%
Facilities	0.0%	0.4%	0.5%
Traveler Safety	4.2%	3.1%	3.1%
Twin Cities Mobility	5.7%	6.8%	0.0%
Greater Minnesota Mobility	0.0%	1.4%	0.0%
Freight	2.8%	2.7%	3.0%
Bicycle Infrastructure	0.8%	0.5%	0.6%
Accessible Pedestrian Infrastructure	1.8%	2.4%	2.7%
RCIP	3.3%	1.2%	1.0%
Project Delivery	14.3%	15.7%	16.0%
Small Programs	6.1%	2.8%	2.3%

Distribution of investments over the 20 years is not uniform. The investment direction has three phases as it transitions from the previous 2013 investment direction to the updated investment direction in MnSHIP 2017. Figure 6-4 shows the difference in investment breakdown over the 20 year time frame.

The first four years (2018-2021) of the MnSHIP investment direction represents the current projects which are being programmed in the STIP. Projects were selected based on 2013 investment direction guidance.

The next two years (2022-2023) of the investment direction reflects a transition between the 2013 MnSHIP investment direction and the updated investment direction in this plan. While the investment direction in these two years begins to shift towards an increased focus on maintaining the existing system over expanding the system, there is continued investment on mobility projects. This represents the continued commitment to invest in mobility projects through 2023 identified in the 2013 plan and continued in this update.

After 2023, the investment direction reflects the priority to maintain the existing highway system. With no investment in mobility projects after 2023, investments in pavement condition, bridge condition and roadside infrastructure increase.

SYSTEM STEWARDSHIP

The MnSHIP investment direction aligns with the System Stewardship objective and strategies in the Statewide Multimodal Transportation Plan. This objective emphasizes maintaining the state's existing National Highway System (NHS), keeping the transportation system on a sustainable track for the future, considering multiple needs in programming and collaborating with partners. 79 miles, or about one percent, of Minnesota’s NHS is not owned by MnDOT. Owners include eight counties, six cities and the Metropolitan Airports Commission (MAC). Most of these segments are CSAH or MSAS routes, and most segments are less than a mile long. MnDOT collects, maintains and reports pavement data on all NHS and state-owned roads. Bridge inventory, inspection and condition data from is housed and reported by MnDOT's Bridge Office for all bridges in the state, regardless of ownership. Centralizing these functions ensures consistencies for all pavement and bridge data and reduces duplication of methodologies.

MnDOT will not be able to invest in all assets at optimal points in their life cycles due to funding limitations. Throughout the 20-year plan, MnDOT will prioritize infrastructure improvements on NHS routes and hold these roads to a higher performance standard than non-NHS routes. This approach allows MnDOT to comply with federal law and manage risks related to statewide travel.

While MnSHIP's emphasis is on maintaining the existing system, MnDOT strives to achieve multiple objectives through coordinated investments. For example, drainage infrastructure (roadside infrastructure condition) helps pavements last longer. Funding bridge condition at a high level of performance for all years of the plan supports traveler safety. Investing in pavement condition can enhance the bicycle and pedestrian network.

MnDOT will ensure that the dollars spent in system stewardship achieve optimal outcomes through:

- Innovation: developing new materials, design standards and procedures
- Low-cost maintenance and repairs: using recycled materials, innovative design and preventative maintenance treatments to extend the useful life of infrastructure without increasing costs
- Alternate bidding: planning for two comparable repair strategies (concrete versus bituminous) for some projects so contractors can bid the most cost-effective solution

In addition to MnSHIP, MnDOT will continue to use planning and research to guide its stewardship of state highway assets. MnDOT's pilot TAMP helped MnDOT coordinate pavement, bridge and roadside infrastructure investments to make the most effective use of limited dollars.

SYSTEM STEWARDSHIP OVERALL OUTCOMES

Pavement, NHS bridges and roadside infrastructure assets will continue to deteriorate over the next 20 years and as a result, MnDOT will:

- Not meet MnDOT targets for any pavement system
- Meet state and federal minimum thresholds for bridge condition with a decrease in overall bridge system condition

Figure 6-5: System Stewardship Performance Targets and Outcomes

INVESTMENT CATEGORY	SYSTEM	TARGET	PROJECTED OUTCOMES (2037)
Pavement Condition	Interstate	2.0% poor (or less)	4.0% poor
Pavement Condition	Other NHS	4.0% poor (or less)	8.0% poor
Pavement Condition	Non-NHS	10.0% poor (or less)	18.0% poor
Bridge Condition	NHS	2.0% poor (or less)	5.0% poor
Bridge Condition	Non-NHS	8.0% poor (or less)	7.0-8.0% poor
Roadside Infrastructure Condition	Culverts	10.0% poor (or less)	14.0-15.0% poor
Roadside Infrastructure Condition	Deep Stormwater Tunnels	10.0% poor (or less)	23.0-24.0% poor
Roadside Infrastructure Condition	Overhead Sign Structures	6.0% poor (or less)	25.0% poor

These targets represent desired performance levels, typically based on lowest life cycle costs, customer expectations or policy priorities. MnDOT used these targets to calculate its estimated 20-year needs in these categories.

It should be noted that some roadside infrastructure assets, the Jurisdictional Transfer and Facilities categories, do not have adopted performance targets. In these cases, investments will be guided based on the goals MnDOT wants to achieve in each investment category.

Figure 6-5 shows MnDOT's performance goals for pavement condition, bridge condition, and certain roadside infrastructure assets for which performance targets have been adopted. The anticipated pavement, bridge and roadside infrastructure conditions on the state highway system are shown in the column on the far right. These outcomes meet the minimum thresholds established for federal performance measures. However, many outcomes do not meet MnDOT targets.

Figure 6-6 summarizes the expected condition of all system stewardship investment categories based on MnDOT's investment priorities for MnSHIP and compares them to the previous set of priorities established in the 2013 plan.

Figure 6-6 System Stewardship Outcomes and Total Investment

INVESTMENT CATEGORIES	OBJECTIVE AREA	EXISTING INVESTMENT DIRECTION	UPDATED INVESTMENT DIRECTION	RATIONALE FOR ADJUSTING EXISTING DIRECTION
Pavement Condition	System Stewardship	48.6%	49.4%	Increase investment to maintain the system, though conditions decline. The NHS system is the priority network for investment and is held in better condition. MnDOT accepts more miles of non-NHS in poor condition. Public and internal feedback was to prioritize investment in maintaining the existing highway system.
Bridge Condition	System Stewardship	20.5%	11.4%	Recent increased investment has improved the condition of bridges. Greater accuracy of deterioration model and forecasted condition has led to increased efficiency of investments to maintain bridge condition. Enables MnDOT to invest less while maintaining acceptable bridge conditions.
Roadside Infrastructure Condition	System Stewardship	8.9%	7.7%	Maintain approximate current investment amount. Prioritize investment concurrent with pavement and bridge projects. Proactively address high-risk elements with stand-alone projects.
Jurisdictional Transfer	System Stewardship	N/A	0.4%	Invest in properly aligning the ownership of the system to provide the right level of service and better meet customer expectations.
Facilities	System Stewardship	N/A	0.4%	Maintain historical investment amount. Previously investment was split between Roadside Infrastructure and Small Programs

Life Cycle Cost Based Project Alternative Selection

MnDOT makes project level scoping investment decisions which consider life cycle costs in particular for pavement and bridge projects. For pavements, a "Pavement Determination" is made based on life cycle costs in order to make a determination 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 utilizes a comprehensive deterministic model which distinguishes between design nuances.

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 a uniform or consistent practice, this represents a rapidly emerging practice within MnDOT as the inventory of assets is completed, and cost data is gathered and modeled.

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 which are suggested by the management systems, and respective costs including both capitally funded actions as well as preventative and reactionary work accomplished by MnDOT's maintenance staff.

During the development of MnDOT's pilot TAMP, life cycle cost analyses (LCCA) were prepared for several asset classes using either deterministic modeling techniques or Markov Chain network level analyses. The analyses generally considered "worst first" (now termed "minimum maintenance only") strategies which represent essentially a run-to-failure approach, an idealized approach which assumed full implementation of preservation treatments at optimum timing such as per MnDOT's pavement manual, and a "typical" scenario representing what MnDOT believes is actually accomplished in the field using best available data to characterize actual investments.

Since preparation of the pilot TAMP, MnDOT has invested significantly in its ability to model internal maintenance costs for routine, reactive and preventative maintenance in accordance with asset condition, and has been able to update the LCCA models accordingly. These models serve to give asset owners an order of magnitude representation of possible savings or efficiencies to be gained through application of best practices, supporting continued culture change necessary for asset management practice advancement.

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

LIFE CYCLE PLANNING

Once a section of state highway is built, the agency is responsible for all future costs to keep that road in service, including the costs to reconstruct components of the road when they reach the end of their physical lives. LCP depends on the ability to forecast both asset condition and future treatment costs out into the future. It uses economic treatments (discounting) to reduce all future costs to current dollars, so that dis-similar 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 preventative 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 judgement of the life of these structures and the degree to which treatment options affect the estimated life.

- Noise Walls: (to be added in final submission)

- Buildings: (to be added in final submission)

- Pedestrian Infrastructure: (to be added in final submission)

- ITS: (to be added in final submission)

A key goal of a Life Cycle Planning effort is to manage assets at the optimal level of maintenance 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 which employ more aggressive preventative maintenance approaches. While they may be exemplary or network-wide in scope, the analyses give decision makers an indication of the savings which can be realized by either adopting or maintaining an aggressive preventative maintenance approach.

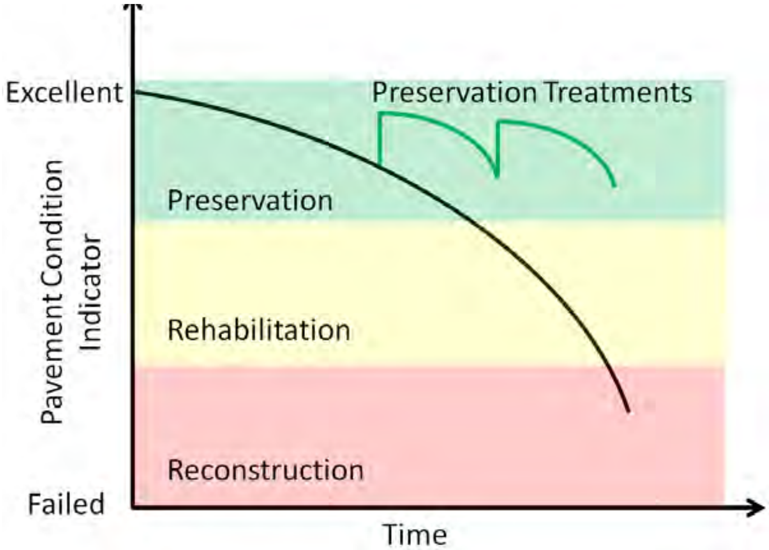
Typically, a well-maintained pavement or bridge, when maintained at a level that minimizes costs in the long-term, is also kept in relatively good condition, and therefore provides a higher level of service over its life, benefiting not only the agency financials, but the users in a direct and tangible way.

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 methodological approach 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 with approaches on a continuum between simply a building and providing a minimum maintenance only scenario to implementing an aggressive preventative maintenance scenario. A typical pavement deterioration model demonstrating the impact of preservation is illustrated in Figure 6-7. 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 preventative maintenance actions, but that the quality of the pavements, and thus service to users, remains higher over time.

Figure 6-7: Deterioration Model Illustrating Impact of Preservation



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

- Creating a pavement preventative maintenance manual
- Staffing a temporary liaison to work between the Materials Office and Districts
- Building PM 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 Office responsibility to work between the Materials Office and district maintenance and materials staff to improve the systematic planning of pavement PM activities
- Development of illustrative materials such as a crack sealing exhibit which shows high benefits resulting from the work MnDOT's 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

Figure 6-8: Scenario 2 Life Cycle Management Strategy for Flexible Pavements

TYPICAL PAVEMENT AGE* (YRS)	AGE RANGE** (YRS)	TREATMENT	TYPICAL CONDITION WHEN APPLIED	TYPICAL COST ($/LN-MI)***	COST RANGE ($/LN-MI)***
0	0	Initial Construction	-	$657,500^	$210,000-$2,000,000
8	6-10	Crack Treatment	Good	$6,000	$3,000-$10,000
12	10-14	Surface Treatment	Good	$15,000	$10,000-$30,000
20	18-22	Mill & Overlay (1st Overlay)	Fair	$155,000*	$145,000-$175,000
24	21-25	Crack Treatment	Good	$6,000	$3,000-$10,000
26	25-29	Surface Treatment	Fair	$15,000	$10,000-$30,000
35	33-35	Mill & Overlay (2nd Overlay)	Fair	$155,000	$145,000-$175,000
39	36-40	Crack Treatment	Good	$6,000	$3,000-$10,000
41	39-43	Surface Treatment	Fair	$15,000	$10,000-$30,000
47	45-49	Mill & Overlay (3rd Overlay)	Poor	$155,000	$145,000-$175,000
51	49-53	Crack Treatment	Good	$6,000	$3,000-$10,000
53	51-55	Surface Treatment	Fair	$15,000	$10,000-$30,000
57	55-59	Mill & Overlay (4th Overlay)	Poor	$155,000	$145,000-$175,000
61	59-63	Crack Treatment	Good	$6,000	$3,000-$10,000
63	61-65	Surface Treatment	Fair	$15,000	$10,000-$30,000
65	63-67	Mill & Overlay (5th Overlay)	Poor	$155,000	$145,000-$175,000
68	66-70	Crack Treatment	Good	$6,000	$3,000-$10,000
70	68-72	Reconstruction	Fair	$657,500^	$210,000-$2,000,000

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

Although it operates in a decentralized decision making environment, most MnDOT districts proactively implement strong pavement preservation programs, though MnDOT currently lacks robust PM tracking data. Also, the decentralized districts are required to manage their entire construction program within their budget, and this sometimes results in impacts to the PM funding setasides in response to unforseen events such as project cost over-runs.

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 6-8, 6-9, and 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). The two flexible pavement strategies were used to prepare example life cycle cost analyses shown in Figure 6-11. These life cycle results highlight the magnitude of differences in costs for each strategy. MnDOT will follow the same process to conduct analyses using the life cycle management strategy for rigid pavements. The unbonded overlay and reconstruction treatments will be separated as two different scenarios considering the wide range of costs between the two, and will be compared to a minimum maintenance only approach.

Figure 6-9: Scenario 1 Life Cycle Management Strategy for Flexible Pavements

TYPICAL PAVEMENT AGE* (YRS)	AGE RANGE** (YRS)	TREATMENT	TYPICAL CONDITION WHEN APPLIED	TYPICAL COST ($/IN-MI)***	COST RANGE ($/IN-MI)***
0	0	Initial Construction	-	$657,500^	$210,000-$2,000,000
8	6-10	Crack Treatment	Good	$6,000	$3,000-$10,000
12	10-14	Surface Treatment	Good	$15,000	$10,000-$30,000
20	18-22	Mill & Overlay (1st Overlay)	Fair	$155,000	$145,000-$175,000
23	21-25	Crack Treatment	Good	$6,000	$3,000-$10,000
27	25-29	Surface Treatment	Fair	$15,000	$10,000-$30,000
35	33-35	Mill & Overlay (2nd Overlay)	Fair	$155,000	$145,000-$175,000
38	36-40	Crack Treatment	Good	$6,000	$3,000-$10,000
43	41-45	Surface Treatment	Fair	$15,000	$10,000-$30,000
50	47-53	FDR/Reconstruction	-	$657,5000^	$145,000-$175,000
58	56-60	Crack Treatment	Good	$6,000	$3,000-$10,000
62	60-64	Surface Treatment	Good	$15,000	$10,000-$30,000
70	68-72	Mill & Overlay (1st Overlay after FDR/construction)	Fair	$155,000	$145,000-$175,000

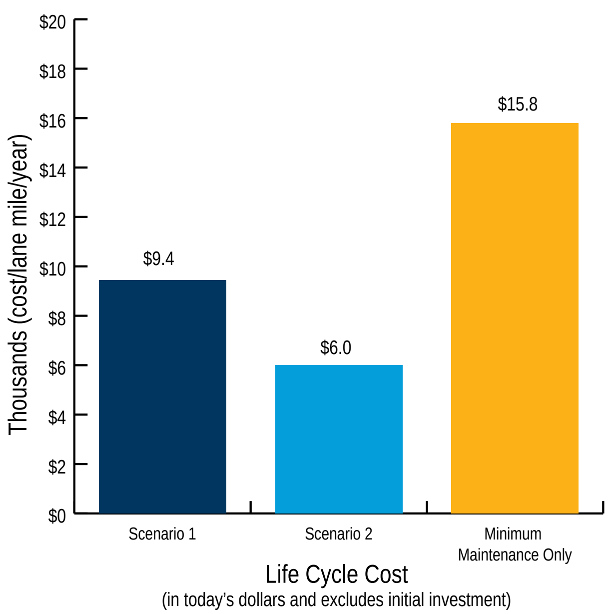
Notes:
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data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

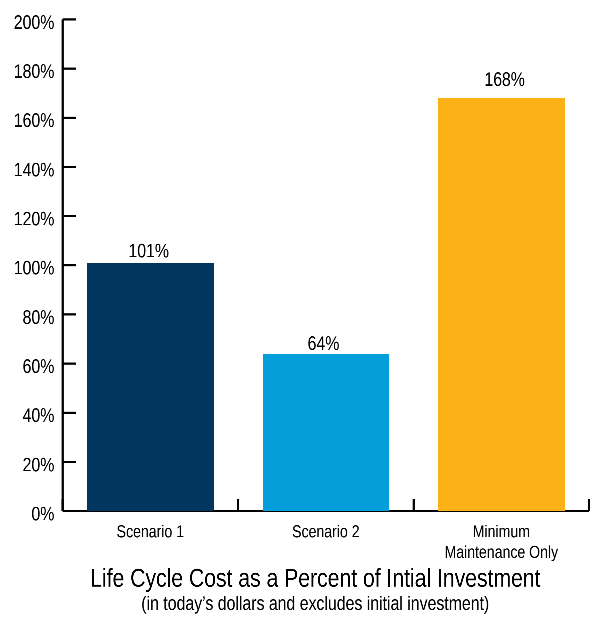
Figure 6-10: Life Cycle Management Strategy for Rigid Pavements

TYPICAL PAVEMENT AGE* (YRS)	AGE RANGE** (YRS)	TREATMENT	TYPICAL CONDITION WHEN APPLIED	TYPICAL COST ($/ LN-MI)***	COST RANGE ($/ LN-MI)***
0	0	Initial Construction	-	$450,000^	$450,000-$2,000,000
10	6-20	Reseal joints and partial depth repair	Good	$10,000	$5,000-$15,000
16	13-31	Minor CPR (some full depth repairs)	Fair	$80,000	$55,000-$80,000
26	8-26	Major CPR (and grinding)	Fair	$230,000	$135,000-$230,000
50	46-54	Unbonded Overlay/Reconstruction	Poor	$450,000^	$450,000-$2,000,000
60	56-70	Reseal joints and partial depth repair	Good	$10,000	$5,000-$15,000
66	63-81	Minor CPR (some full depth repairs)	Fair	$80,000	$55,000-$80,000

The Pavement Work Group indicated that the desired and typical life cycle strategies are fairly close for rigid pavements and recommended using the same values for both
* Based on Values from MnDOT Pavement Design Manual Chapter 7 and input provided by MnDOT TAMP Pavement Work Group
** Range assumed based on general input from MnDOT TAMP Pavement Work Group
***Cost data provided by MnDOT TAMP Pavement Work Group, some assumptions to develop cost ranges based on data provided
^ Value based on assumption that typically, 75% of the projects involve FDR and 25% involve complete reconstruction

Figure 6-11: Life Cycle Results (Flexible Pavements)





Costs shown in this figure combine the efforts of contractors as well as MnDOT internal staff. As conditions are maintained at a higher level, reduced amounts of maintenance staff work are necessary. MnDOT internal staff costs are lower than contracted costs for some crack sealing work, but those reductions have not been incorporated here.

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 preventative maintenance such as annual deck flushing, periodic crack, deck, and rail sealing, joint maintenance, bearing replacement and other preventative maintenance activities.

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 Safety 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 actions – flushing, crack sealing, painting, etc. – are typically performed by internal staff according to an assigned frequency recommended by its SIMS (Structure Inventory Management System) which considers criteria such as the activity performed, bridge age and type, condition, and traffic volume and control. 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). Staffing, funding, work zone traffic control limitations on high-volume bridges (typically on Interstate Highways) and other system priorities constrain MnDOT from being able to flush all bridges annually. Reactive maintenance actions, like patching, are performed based on conditions noted in the inspections and tracked in SIMS.

Figure 6-12: Corrosion on a Bridge Structure Element

Figure 6-13: Costs and Treatment Strategies used in the LCP Model for Bridge Structures

TREATMENT	$/BRIDGE	% BRIDGES ACTED UPON ANNUALLY			
		GOOD	SATISFACTORY	FAIR	POOR
ROUTINE MAINTENANCE: BRIDGE DECKS					
Joint sealing	$1,529	13%	13%	13%	
Deck sealing	$37,406	14%	14%	14%	
Crack sealing	$1,500	20%	20%	20%	
ROUTINE MAINTENANCE: BRIDGE SUPERSTRUCTURES					
Inspection	$1,111	60%	60%	60%	60%
Flushing	$500	75%	75%	75%	75%
Lube bearings	$26,600	0.1%	0.2%		
ROUTINE MAINTENANCE: BRIDGE CULVERTS					
Inspection	$1,111	60%	60%	60%	60%
CORRECTIVE ACTION: BRIDGE DECKS					
Joint repair (patch)	$38,215		1%	2%	
Deck repair	$16,833		2%	35%	15%
Overlay	$130,921			5%	2%
Rail repair/replace	$127,705		1%	5%	
CORRECTIVE ACTION: BRIDGE SUBSTRUCTURES					
Patching	$56,070			10%	15%
Slope paving repair	$26,166		1%	1%	
Erosion/Scour repair	$25,000			5%	5%
CORRECTIVE ACTION: BRIDGE SUPERSTRUCTURES					
Spot painting	$19,500		2%	5%	
Full painting	$377,480		3%	5%	
Patching	$30,000		1%	3%	5%
Repair/replace bearings	$46,549				5%
Repair steel	$50,000			2%	5%
CORRECTIVE ACTION: BRIDGE CULVERTS					
Patching	$12,104			5%	10%
REHAB AND REPLACEMENT: BRIDGE DECKS					
Redeck	$1,122,184				5%
REHAB AND REPLACEMENT: BRIDGE SUBSTRUCTURES					
Replace elements	$100,000				1%
REHAB AND REPLACEMENT: BRIDGE SUPERSTRUCTURES					
Replace elements	$100,000				1%
Replace structure	$2,702,941				20%
REHAB AND REPLACEMENT: BRIDGE CULVERTS					
Replacement	$250,000				25%

Bridges and culverts deteriorate over time. Steel beams and reinforcing steel in particular is prone to corrosion. Paint and concrete cover the steel and protect it from corrosion (see Figure 6-12). But paint and concrete are often exposed to weather, traffic, erosion, animals, chemicals and collisions, and therefore require preventative 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 utilizes information from its SIMS and inspection programs to forecast needs and track work performed.

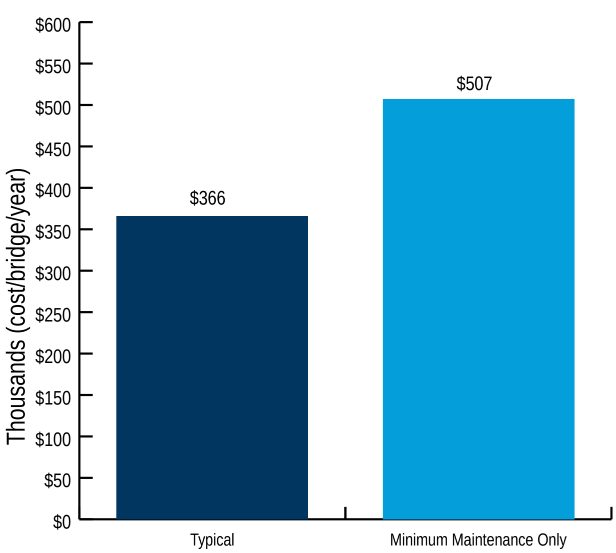
Most bridges have expansion joints and bearings to prevent damage due to temperature changes and motion. These features can sometimes be damaged by the constant pounding of trucks passing over them, corrosion, excessive movement or intrusion by rocks and other foreign materials. Leaking expansion joints can lead to increased deterioration of underlying elements due to greater exposure to deicing chemicals. MnDOT utilizes internal staff to replace glands and otherwise perform preventative joint maintenance to minimize damage caused by leaks at joints.

Bridge culverts tend to be more durable, and require very little maintenance due to the fact that 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.

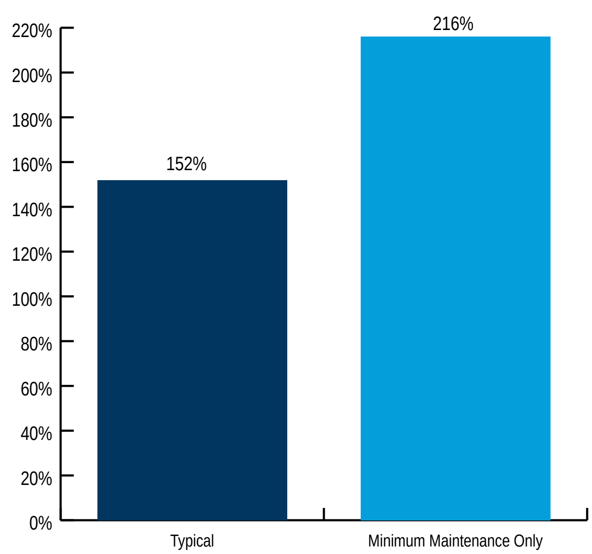
Figure 6-13 (used as input in the network-wide life cycle cost analysis) identifies treatment practices followed by the department, the relative costs of each and the historic performance frequency.

MnDOT's typical preventative maintenance strategies are believed to extend the average service life of each structure from about 50 years to about 80 years and save considerable sums compared to a minimum maintenance only strategy (see Figure 6-14).

Figure 6-14: Life Cycle Results (Bridges)



Life Cycle Cost
(in today's dollars and excludes initial investment)



Life Cycle Cost as a Percent of Intial Investment
(in today's dollars and excludes initial investment)

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS

Hydraulic infrastructure, including highway culverts (diameter less than 10 feet) and deep storm water tunnels, helps MnDOT effectively manage water flows throughout the state. Highway culverts convey surface water runoff under and adjacent to the state highway system. Deep stormwater tunnels are located in the Twin Cities Metropolitan Area, collect stormwater runoff (e.g. runoff from major highways and surrounding community), and are approximately 50-100 feet below the surface. MnDOT maintains an inventory of more than 40,000 highway culverts on the state highway system, which includes NHS and non-NHS highways. These have a replacement value of approximately $1.6 billion. Culverts are inspected on an interval that is based on condition and risk: new assets are inspected every six years, while those in poor condition may be inspected every year or every other year. 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 its 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 very long life.

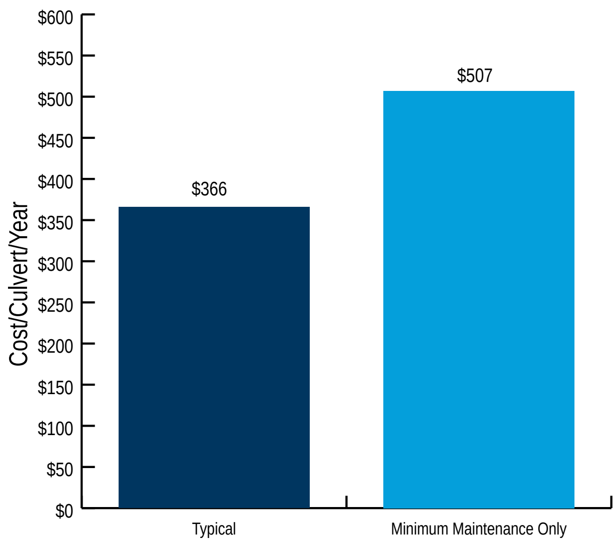
Drainage culverts do gradually deteriorate, exhibiting corrosion, settlement, deformation, scour from floods, impact damage and buildup of debris. One relatively common problem is leakage where water intrudes into surrounding soil and washes it away, creating voids. The presence of these pockets tends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

MnDOT performs maintenance activities on approximately two percent of the highway culverts per year, including resetting culvert ends, repairing joints, culvert lining, culvert replacement, and paving the lower interior of the culverts. Costs of the work of its staff is tracked on an individual culvert basis using custom developed software (MnDOT transitioned all culvert management data to TAMS in February of 2018). Figure 6-15 shows the activities routinely accomplished and the associated costs.

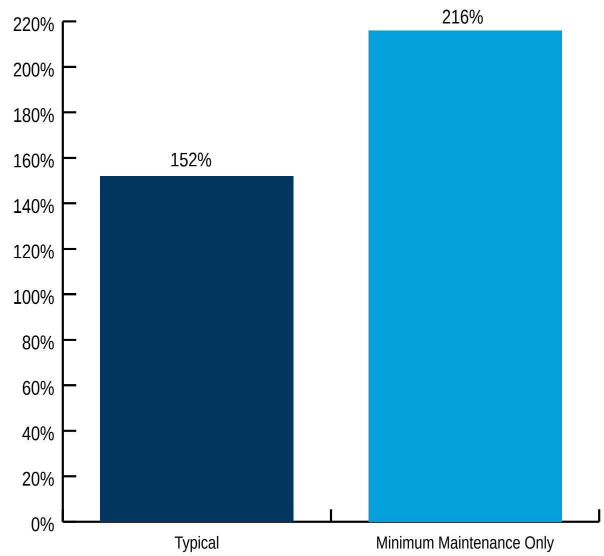
Figure 6-15: Culvert Maintenance and Repair Activities

TREATMENT	UNIT	COST/UNIT
Inspection	Each	$70
Cleaning	Each	$380
Reset Ends	Each	$3,000
Joint Repair	Each	$3,300
Pave Invert	Linear Foot	$22
Replace Ends	Each	$5,800
Slipliner	Each	$12,000
Cured Inplace Liner	Each	$25,000
Trench Replacement	Each	$38,000
Jack Replacement	Linear Foot	$788

Figure 6-16: Life Cycle Results (Highway Culverts)



Life Cycle Cost
(in today's dollars and excludes initial investment)



Life Cycle Cost as a Percent of Intial Investment
(in today's dollars and excludes initial investment)

The life cycle results for highway culverts highlight the magnitude of differences in costs for each strategy are shown in Figure 6-16.

MnDOT, in partnership with the City of Minneapolis, maintains an inventory of eight deep storm water tunnels that are comprised of varying lengths ranging from 0.2 to 4.6 miles and covering a total combined length of 73,392 linear feet. All eight tunnels have had detailed inspection studies completed, which identify specific conditions and repairs. The City of Minneapolis also performs a visual walk-through inspection of tunnels every two to five years. Tunnel conditions range from the fair to poor condition with 81% in fair condition and 19% in poor condition. Typical maintenance consists primarily of repairing cracks and drilling and grout filling the annular space between the outside of the concrete liner and the eroded sandstone native soil. Data for the Life Cycle Planning are based on MnDOT's expert opinion and historical experience, and are considered to be rough estimates. The best available estimate is that the total replacement value of these assets is approximately $372 million and the future life cycle maintenance costs range from 2.5 to 2.8 times the initial cost of the tunnel.

OVERHEAD SIGN STRUCTURES AND HIGH-MAST LIGHT TOWER STRUCTURES

MnDOT maintains an inventory of approximately 1,900 overhead sign structures and 478 high-mast light tower structures statewide. Current replacement values of all overhead sign structures and all high-mast light tower structures are approximately $175 million and $19 million, respectively. 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. A less-formalized element-level inspection process and rating system is used for overhead sign structures in non-Metro 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.

Figure 6-17 shows a typical overhead sign structure in the Twin Cities metro area. Sign structure inspection is newly implemented. 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.

Figure 6-17: Overhead Sign Structure

Typical reactive maintenance activities performed on overhead sign structures include tightening nuts and removing grout. Minor rehabilitation activities performed include re-grading footing, replacing welds, removing catwalks/ lighting, and replacing individual elements. Typical maintenance actions 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 which give confidence in the costs of owning these assets.

The life cycle cost analysis results for overhead sign structures and high-mast light tower structures highlighting the magnitude of differences in costs for each strategy are shown in Figures 6-18 and 6-19.

Figure 6-18: Life Cycle Results (Overhead Sign Structures)

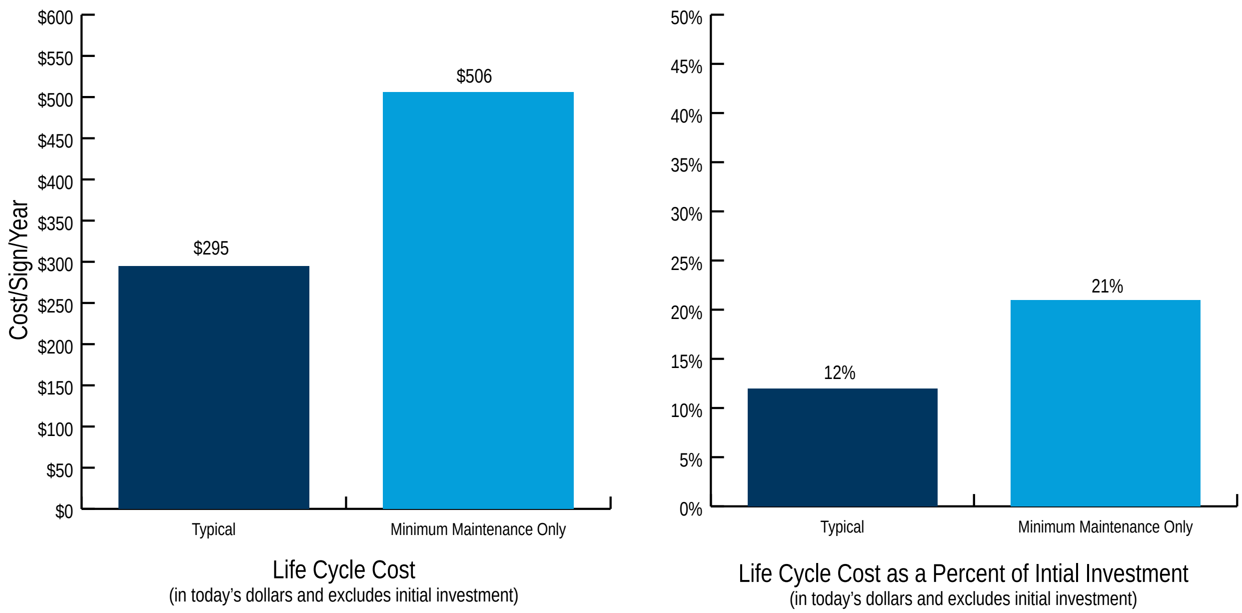
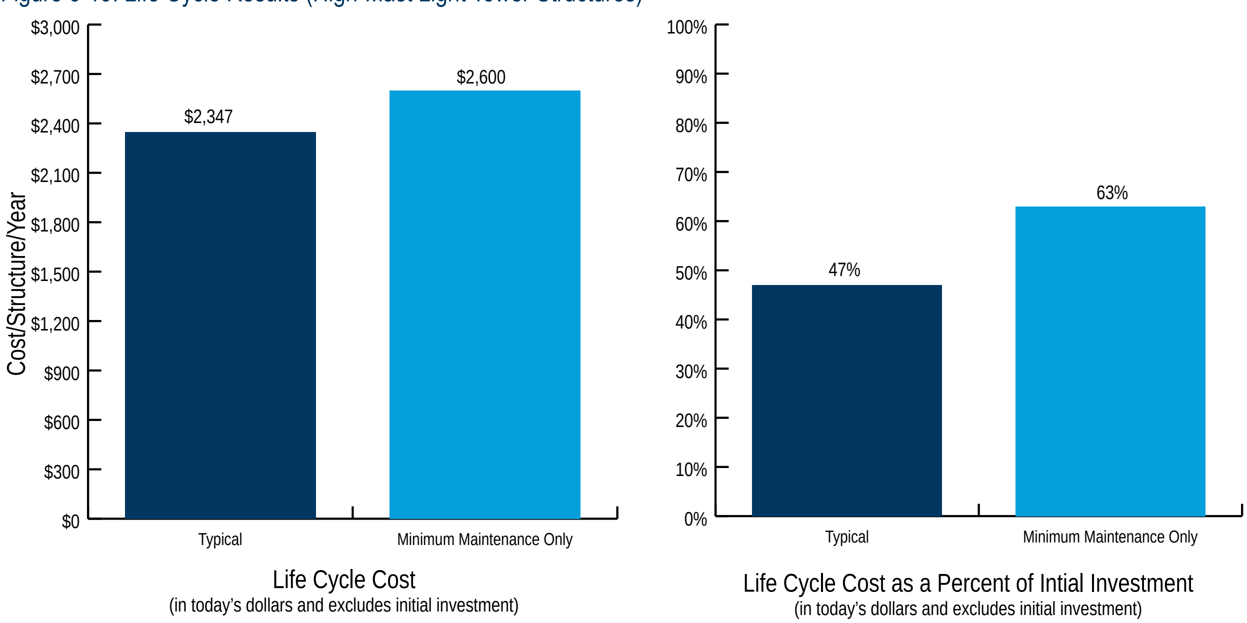


Figure 6-19: Life Cycle Results (High-Mast Light Tower Structures)



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

NOISE WALLS

(Text will be added for final submission)

SIGNALS

MnDOT maintains an inventory of approximately 1,300 Traffic Signal Systems. Many of the systems are managed in collaboration with local jurisdictions in accordance with agreements which were executed at the time of construction.

The inventory, condition data, and maintenance history and cost information is captured via, and stored in MnDOT's TAMS. As a result of these efforts, MnDOT's confidence in the data is relatively high. Data from TAMS, in addition to public and other means of receiving notification of system problems from stakeholders, is used to determine work tasks to perform on systems.

MnDOT estimates the lifespan of a typical signal system at 30 years if maintained on a "minimum maintenance only" basis, and projects that system life can be increased by 10 years with preventative maintenance.

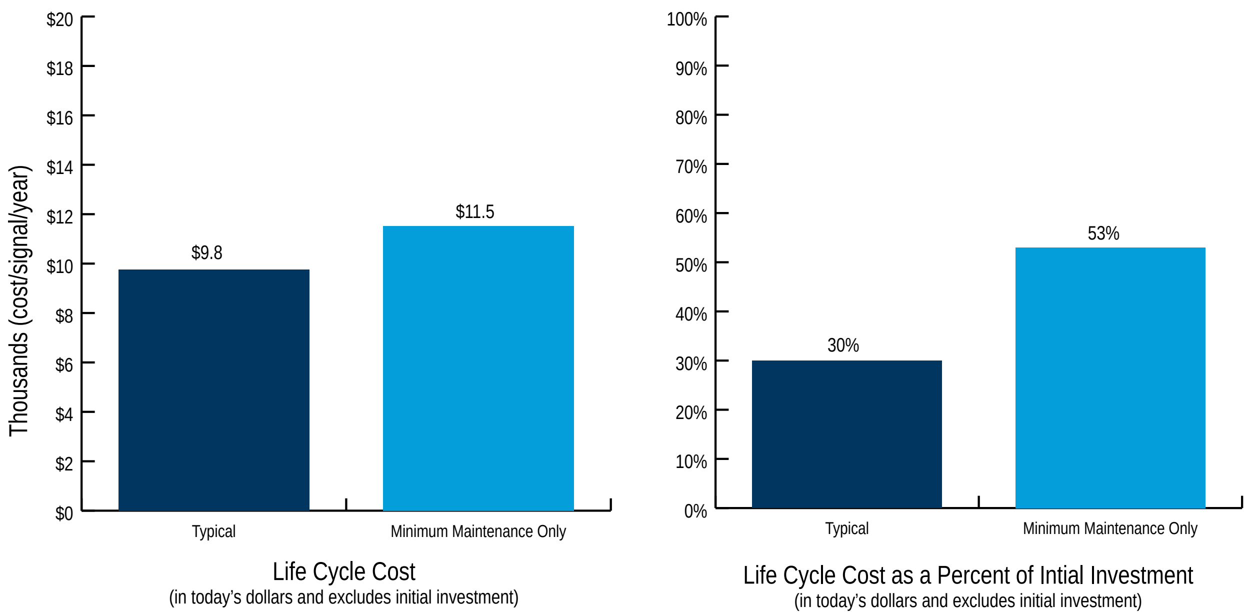
Reactive and Preventative maintenance activities are shown in Figure 6-20

Figure 6-20: Signals Maintenance and Repair Activities

TREATMENT	UNIT	COST/UNIT
Reactive Maintenance	Each	$399
Operations Check	Each	$380
Electrical Preventative Maintenance	Each	$124
Electronic Preventative Maintenance	Each	$132
Replace LED indicators	Each	$20,000
Replace Electronics	Each	$30,000
Structural Inspection	Each	$1,000

The life cycle cost analysis results for traffic signal systems highlights the magnitude of differences in costs for each strategy are shown in Figure 6-21.

Figure 6-21: Life Cycle Results (Signals)



LIGHTING

MnDOT maintains an inventory of approximately 27,000 roadway lighting system poles. The inventory, condition data, and maintenance history and cost information is captured via, and stored in MnDOT's TAMS. As a result of these recent efforts, MnDOT's confidence in the data is growing. Data from TAMS, in addition to local district knowledge, is used to determine work tasks to perform on systems.

MnDOT estimates the lifespan of a typical system element at 30 years if maintained on a "minimum maintenance only" basis, and projects that system life can be increased by 10 years with preventative maintenance.

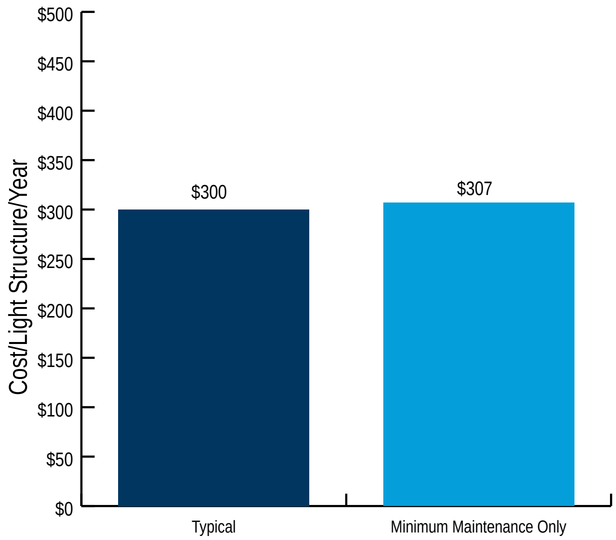
Reactive and Preventative maintenance activities are shown in Figure 6-22.

Figure 6-22: Lighting Maintenance and Repair Activities

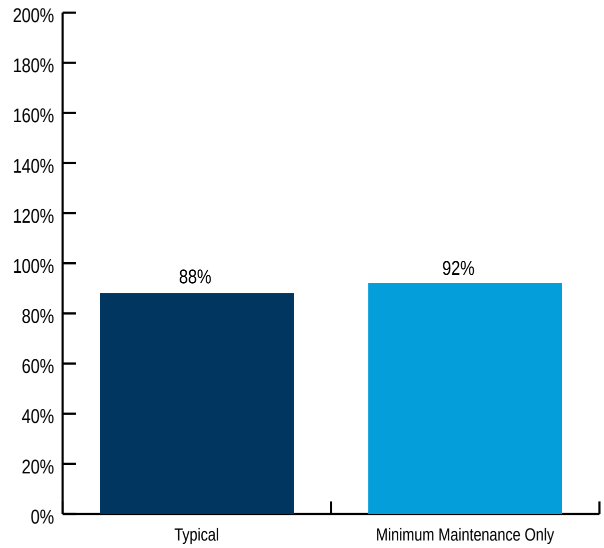
TREATMENT	UNIT	COST/UNIT
Knockdowns	Each	$1,978
Reactive Maintenance	Each	$1,841
Electrical Inspection	Each	$55
Replace LED Luminaires	Each	$500
Structural Inspection	Each	$140

The life cycle results for roadway lighting poles highlighting the magnitude of differences in costs for each strategy are shown in Figure 6-23.

Figure 6-23: Life Cycle Results (Lighting)



Life Cycle Cost
(in today's dollars and excludes initial investment)



Life Cycle Cost as a Percent of Intial Investment
(in today's dollars and excludes initial investment)

PEDESTRIAN INFRASTRUCTURE

(Text will be added for final submission)

BUILDINGS

(Text will be added for final submission)

ITS

(Text will be added for final submission)

Summary of Life Cycle Cost Estimates

The information presented in the previous analyses provides insight into MnDOT's desired maintenance practices, and illustrates how much it costs per year to maintain an asset when costs are presented in an Equivalent Uniform Annual Cost (EUAC) 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 life spans of these assets. Currently, MnDOT does not have fully-implemented tools, nor sufficiently nuanced historical and forecasting data, to optimize preservation practices objectively, though numerous improvements have been made across all asset classes referenced as a result of increased focus since preparation of its pilot TAMP. As a result, it is believed that 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 6-24 for a cross-asset comparison of annualized life cycle costs.

Figure 6-24: Annualized Life Cycle Cost Estimates by Asset

ASSET CLASS	ANNUALIZED COST RANGE
Pavements (bituminous)	$5,994 - $15,802 per lane-mile
Bridges	$36,000 - $56,000 per bridge
Highway Culverts	$366 - $507 per small culvert
Overhead Sign Structures	$295 - $506 per structure
High-Mast Light Tower Structures	$2,347 - $2,600 per structure
Noise Walls	TBD
ITS	TBD
Signals	$9,754 - $11,529
Lighting Poles	$300 - $307
Pedestrian Infrastructure	TBD
Facilities	TBD

MnDOT generally 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 aggressively working to implement the recommendations of that effort. One recommendation from this assessment is to consider asset valuation in Asset Management Planning. This translates infrastructure conditions into monetary terms, which gives a more economic approach to reporting asset value. As part of the final TAMP submission, MnDOT plans to include current asset valuation in addition to the asset replacement values that are found in Chapter 4. This value will be calculated in coordination with the expert work groups for each asset. The methodology will vary depending on the availability of condition data and deterioration curves for the asset, but will consider techniques already in place in other states. 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.

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 existing and desired performance.

This chapter presents condition results alongside existing targets and target recommendations for assets on the state highway system. These target recommendations provide points of reference for evaluating condition and the adequacy of MnDOT's planned investment. New targets for high-mast light tower structures, buildings, ITS, noise walls, pedestrian infrastructure, traffic signals and lighting have the potential to elevate the importance of these asset categories and provide a basis for developing and evaluating investment strategy alternatives.

STATUS OF TARGETS APPEARING IN THE TAMP

TAMP includes a mix of existing state targets, required federal targets and target recommendations. The existing state targets were established as part of the pilot TAMP for pavements, bridges, culverts, deep stormwater tunnels and overhead sign structures. The target recommendations in this document reflect the expert judgment of MnDOT staff about additional assets and were identified having considered a combination of current policy and investment direction, federal and state requirements, risk, expected or anticipated deterioration, principles of life cycle costs and public expectation.

Chapter 2 further 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 process outcomes and how they were used to help identify targets and outcomes for condition.

Expert work groups developed asset-specific target methodologies based on existing and anticipated future conditions, current information on capital and maintenance investments, anticipated deterioration and risk. For example, the Hydraulic work group identified the number of culverts in poor and very poor condition, determined how many of them deteriorate to a worse condition annually, made judgments on the length of time that a culvert should remain in poor or very poor condition given risk, and determined how many culverts could feasibly be repaired annually.

The 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 2, 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 the federal performance measures. The federal targets have not yet been approved by MnDOT so the gap analysis cannot be completed. However, MnDOT plans to adopt targets that can be met with existing funding.

Figure 7-1: Federal Performance Measures and Targets

ASSET TYPE	PERFORMANCE MEASURE	EXPLANATION	FEDERAL TARGET
Pavements	Share of Interstate and non-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	TBD
Bridges	Share of NHS bridge deck area in good or poor condition	Measure is based on NBI condition ratings	TBD

Existing 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 asset targets and the 10-year expected outcome.

PAVEMENT TARGETS

As part of the pilot TAMP, MnDOT recommended setting a target of no more than two percent poor pavement on the Interstate system and no more than four 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.

As part of the pilot TAMP, MnDOT also recommended adopting a non-NHS pavement condition target of no more than 10 percent poor. This target, which is a slightly higher than existing conditions, is less aggressive than the no more than three percent poor target MnDOT 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 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.

Figure 7-2: Pavement Condition State Targets

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%

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 slightly from 4.7 percent in 2017 to 2.6 percent in 2027. The share of non-NHS deck area on poor condition bridges is expected to increase from 2.1 percent to 3.7 percent, but this remains below MnDOT's target of 8 percent.

Figure 7-3: Bridge Condition Targets

System	2017 Condition (% Poor)	Target (% Poor)	10-year Expected Outcome (% Poor)
NHS	4.7%	≤ 2%	2.6%
Non-NHS	2.1%	≤ 8%	3.7%

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%	NA%

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, recommends that MnDOT establish a target of no more than six percent of its 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%

TAMP Target Recommendations

Since the completion of the pilot TAMP, MnDOT has worked diligently to include additional assets in the TAMP and refine targets for assets included in the pilot TAMP. Expert work groups for each asset identified a recommended performance target which 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. The target setting methodologies are described in more detail for each asset below. Specific targets may be approved, modified or rejected through MnDOT's public planning process and senior leadership review. For the final TAMP 2018, MnDOT plans to host a workshop to verify all TAMP asset targets, while considering associated risks, to ensure that target decisions are made with a broad cross-asset perspective. This workshop will include asset-specific work groups, the TAMP Advisory Group and members of MnDOT's Asset Management Steering Committee.

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

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

Asset	2017 Condition (% Poor)	Draft Target (% Poor)	10-year Expected Outcome (% Poor)
High-Mast Light Tower Structures	18%	≤ 6%	NA

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.

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)	Draft 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%	≤ 8%	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%	≤ 14%	29%
Small Truck Storage - small crew area (Truck Stations, State Sign Shop, Metro Fleet Bldg. and Bridge Crew Buildings).	1%	≤ 8%	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 partially heated) - minimal heating equipment such as unit heaters or space heaters.	4%	≤ 8%	10%
Storage (unheated) - these vary in construction type and range from pole barn type structures to small yard type storage sheds.	8%	≤ 15%	14%
Office Buildings - for the most part, the entire building has finishes consistent with a typical office building.	0%	≤ 10%	0%
Other - there is great difference between all of these buildings and don't easily fit into one of the other categories above.	15%	NA	NA

ITS TARGETS

Like buildings, ITS also has several sub-categories with different target setting methodologies. User impact was a large factor in ITS target setting. For example, several sub-categories were prioritized due to significant public safety issue 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.

Agency asset experts determined that obsolescence will drive replacements far before many ITS assets reach the end of their life expectancy.

Figure 7-8: ITS Condition Targets

Asset	2017 Condition (% Poor)	Draft Target (% Poor)	10-year Expected Outcome (% Poor)
Fiber communication network (miles)	10%	≤ 4%	N/A**
Fiber network shelters	10%	≤ 5%	
TMS (traffic management system) cabinet	13%	≤ 7%	
Dynamic Message Signs	15%	≤ 7%	
Traffic monitoring cameras	10%	≤ 5%	
Traffic Detector Stations/Site -loops and radar (5 mobile units not included in count)	4%	≤ 2%	
Communication Equipment - Ethernet Backbone Devices - Ethernet Communication Equipment - Video Transmission Equipment - Video En/Decoding Devices (pairs)*	20%	≤ 5%	
MnPASS Readers	0%	≤ 2%	
Reversible Road Gates	0%	= 0%	
Ramp Meters	0%	≤ 2%	
Intersection Warning Systems (RICWS)	0%	≤ 6%	
Road Weather Information Systems Sites (RWIS)	0%	≤ 2%	
Automatic Traffic Recorders (ATR)	NA	≤ 10%	
Weigh-In-Motion System (WIM) Sites	NA	≤ 10%	
Road Closures	0%	≤ 10%	

* 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

MnDOT's noise wall program has minimal maintenance needs, resulting in a low percentage of current assets in poor condition. Targets were in alignment with current conditions, which allows MnDOT to continue current management practices. A majority of funding is spent on replacement or major rehabilitation. Target setting encourages more money to be spent on preventative maintenance to extend the life of noise walls.

Figure 7-9: Noise Walls Condition Targets

Asset	2017 Condition (% Poor)	Draft Target (% Poor)	10-year Expected Outcome (% Poor)
Noise Walls	11%	≤ 2%	17%

PEDESTRIAN INFRASTRUCTURE TARGETS

The Americans with Disabilities Act (ADA) is the main driver for pedestrian infrastructure condition targets. Desired targets were set in alignment with ADA compliance standards, which are outlined in the ADA Transition Plan.

Figure 7-10: Pedestrian Infrastructure Condition Targets

Asset	2017 Compliance (% Non-ADA Compliant)	Draft Target (% ADA Compliant)	10-year Expected Outcome (% ADA Compliant)
Pedestrian Infrastructure	73% Curb Ramps 33% Sidewalks	≤ 6% Curb Ramps ≤ 5% Sidewalks	39% Curb Ramps 19% Sidewalks

TRAFFIC SIGNALS AND LIGHTING TARGETS

Agency asset experts determined that the traffic signals and lighting risks were similar to those of overhead sign structures, which carry safety related concerns. Targets were set in alignment with the overhead sign structure targets.

Figure 7-11: Traffic Signals and Lighting Condition Targets

Asset	2017 Condition (% Poor)	Draft Target (% Poor)	10-year Expected Outcome (% Poor)
Traffic Signals	29%	≤ 6%	26%
Lighting	38%	≤ 6%	38%

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

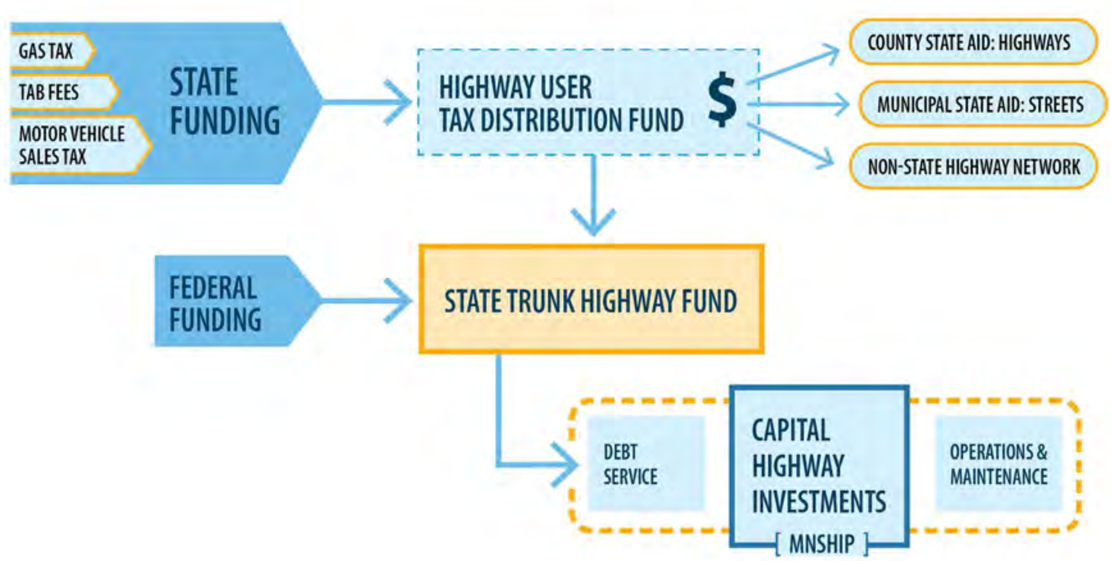
The revenues from Federal-aid go directly to the State Trunk Highway Fund (see Figure 8-1), which funds capital improvements on the state highway system. Revenues from the main state sources, as well as various smaller revenues, are pooled into the Highway User Tax Distribution Fund (HUTDF) and divided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

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

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

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 (VMT) 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 continue 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.

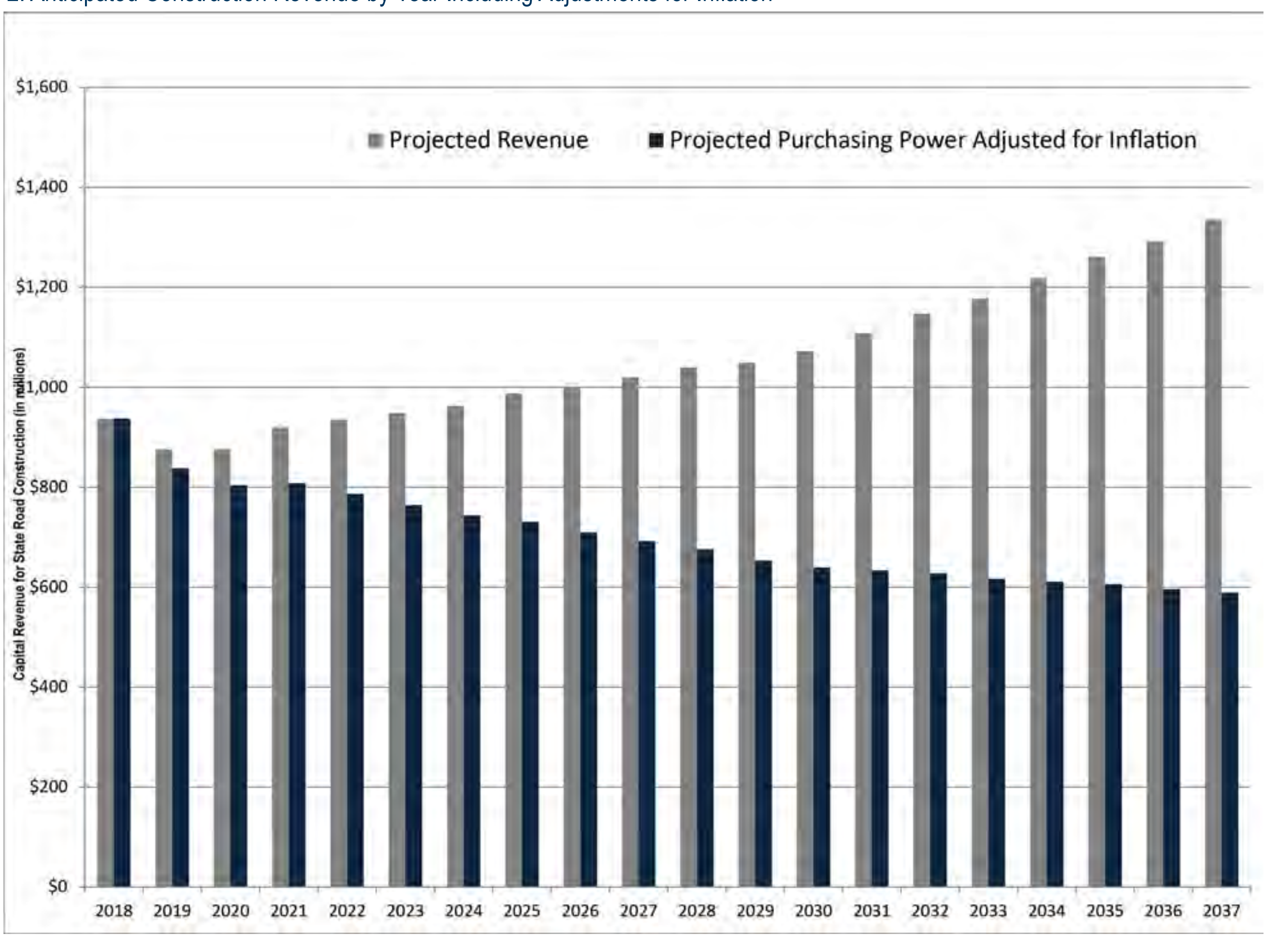
Revenue and Inflation

CAPITAL

Over the next 10 years, MnDOT estimates that $8.8 billion in revenue will be available for capital investment on the state highway system – approximately $880 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 annual buying power (blue) versus nominal revenues (grey) in future years of

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

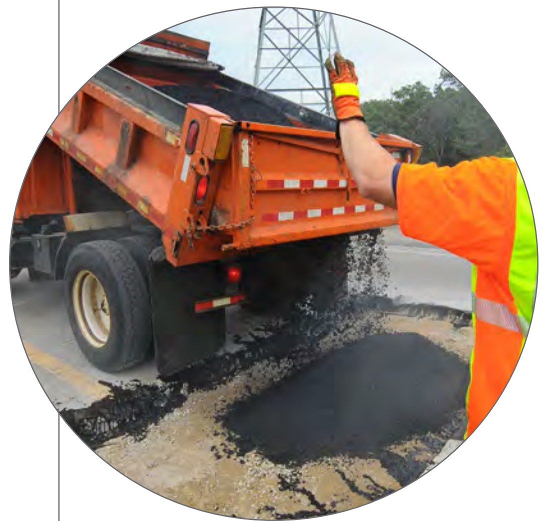


construction. The net effect is that inflation will erode over half the buying power of revenues by 2037, given the assumptions stated above. Figure 8-3 illustrates annual construction revenue over the next ten years.

Figure 8-3: Anticipated Construction Revenue

FISCAL YEAR	CONSTRUCTION REVENUE
2018	$937
2019	$875
2020	$876
2021	$919
2022	$934
2023	$948
2024	$962
2025	$987
2026	$1,001
2027	$1,020

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



OPERATIONS AND MAINTENANCE

MnDOT has a Maintenance and Operations workforce of approximately 2,000 employees spread across seven greater Minnesota districts and one Metro district. 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 (GIS) 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 utilization 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 which 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.

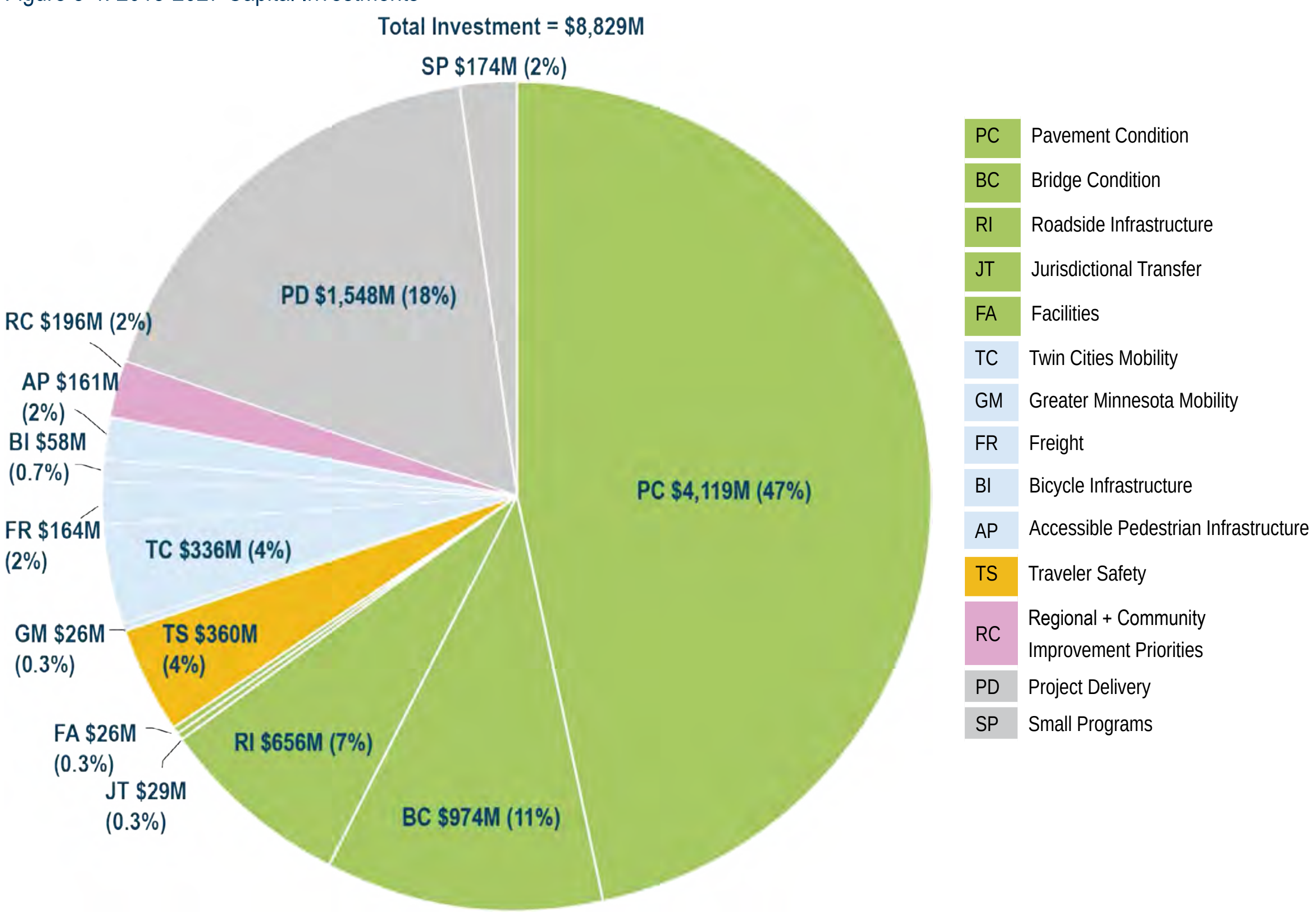
Funding Program Overview

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 (Figure 8-4) - while maintaining some flexibility to address unique risks and circumstances at the district level. Investment totals in the TAMP are based on the 2018-2021 STIP and the 2018-2027 CHIP and have not been updated to reflect any additional revenue changes.

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.

Figure 8-4: 2018-2027 Capital Investments



The SPP selects projects that continue MnDOT's 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 (RCIPs) 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 system 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 (VMT)	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 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 system stewardship 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 and weigh stations and scales.

Distribution of investments over the next 20 year is not uniform. The investment direction has three phases as it transitions from a balanced investment direction to a preservation focused investment direction. Figure 8-7 shows the difference in investment breakdown over the next 20 years.

The first four years (2018-2021) of the MnSHIP investment direction represent the current projects which are being programmed in the STIP. These projects were selected based on 2013 investment direction guidance.

The next two years (2022-2023) of the investment direction reflect a transition between the 2013 MnSHIP investment direction and the updated investment direction in the current MnSHIP. While the investment direction in these two years begins to shift towards an increased focus on maintaining the existing system over expanding the system, there is continued investment in mobility projects. After 2023, the investment direction reflects the priority to maintain the existing highway system. With no investment in mobility projects after 2023, investments in pavement condition, bridge condition, and roadside infrastructure increase.

Figure 8-7: Investment Breakdown By Fiscal Year

INVESTMENT CATEGORIES	FY 2018-2021	FY 2022-2023	FY 2024-2037
Pavement Condition	33.5%	47.3%	52.9%
Bridge Condition	15.6%	8.2%	9.7%
Roadside Infrastructure	8.7%	6.9%	7.7%
Jurisdictional Transfer	0.0%	0.5%	0.5%
Facilities	0.0%	0.4%	0.5%
Traveler Safety	4.2%	3.1%	3.1%
Twin Cities Mobility	5.7%	6.8%	0.0%
Greater Minnesota Mobility	0.0%	1.4%	0.0%
Freight	2.8%	2.7%	3.0%
Bicycle Infrastructure	0.8%	0.5%	0.6%
Accessible Pedestrian Infrastructure	1.8%	2.4%	2.7%
RCIP	3.3%	1.2%	1.0%
Project Delivery	14.3%	15.7%	16.0%
Small Programs	6.1%	2.8%	2.3%

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

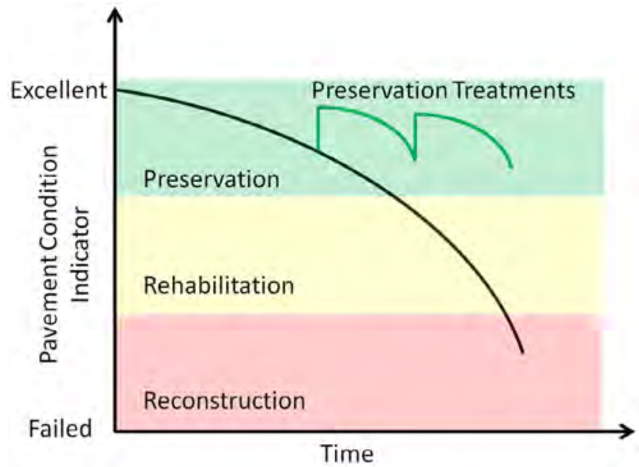
MnDOT's Highway Pavement Management Application (HPMA – discussed in Chapter 5) is used to determine the investment needs and outcomes developed for MnSHIP. A conceptual model of typical pavement deterioration is shown in Figure 8-8.

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 that 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: annual average daily traffic (AADT), safety, the economic importance of the highway corridor, public perception and customer satisfaction.

- Pavement Age and Condition: Approximately 60 percent of Minnesota's state highways were originally 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 8-8: Conceptual Model of Pavement Deterioration



- **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 which will speak to the appropriateness of trading some short term target achievement for longer term cost effective investment strategies.

- **Pavement 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 preventative maintenance. Preventative maintenance is supplemented by MnDOT maintenance, which is funded through our operations budget. MnDOT is working to enhance the accounting for the effects of preventative maintenance in it's pavement modeling.

Between 2018 and 2027, MnDOT identifies capital pavement expenditures of $668 million on Interstate pavements, $2.1 billion on the non-Interstate NHS and $2.1 billion on the non-NHS system, for a total of $4.9 billion. Investments

Figure 8-9: Yearly Pavement Investment by Work Type

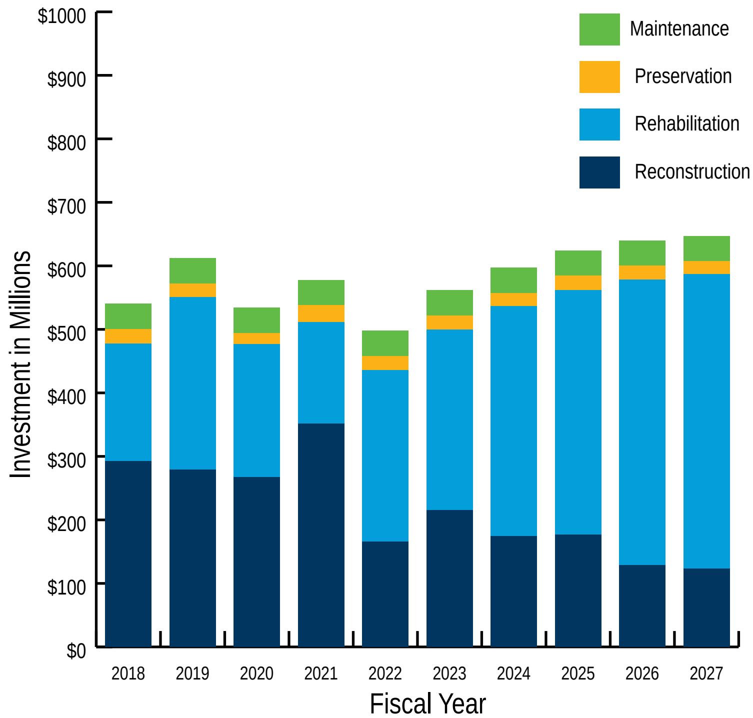
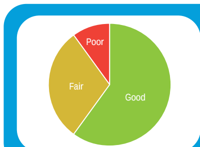
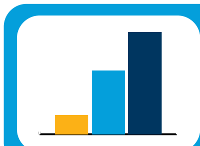


Figure 8-10: MnDOT Typical Preventive/Corrective Actions Investment Strategy for Pavements



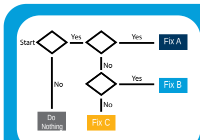
Determine initial fraction of statewide system in good, fair and poor conditions



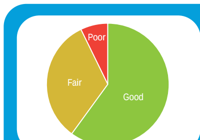
Using pavement investment levels developed from MnSHIP, determine the amount of miles of major rehabilitation and preventative maintenance work that can be constructed

Route	Beg_RP	End_RP
I-94	23.342	29.652
MN 101	145.237	154.877
US 169	250.481	263.122
MN 18	83.453	91.434
MN 6	101.231	105.445

Develop a candidate list of pavement segments which address the miles of major rehabilitation and preventive maintenance
•NHS projects are managed centrally at a statewide level
•Non-NHS projects are managed at the district level



Using the pavement decision tree, determine the right pavement treatment for each pavement segment



Determine a revised fraction of segments in good, fair and poor conditions if the candidate segments in step 3 have been addressed

in pavement preservation and operational/routine maintenance will total approximately $35-40 million annually. Breaking the investment out by type of fix, MnDOT anticipates investing $2.2 billion on reconstruction projects, $3 billion on rehabilitation projects, and $216 million on preventative maintenance over the next ten years. Figure 8-9 show yearly investment by work type. 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 five percent. The typical strategy used by MnDOT to determine the location of pavement investments is summarized in Figure 8-10.

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

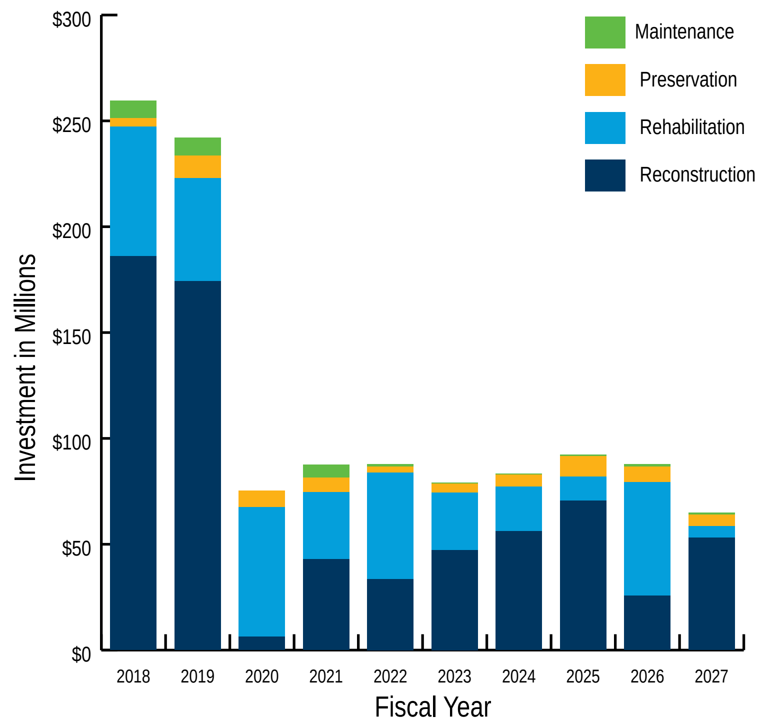
Approximately $10-15 million is spent each year on bridge inspection and maintenance using funds from the operations budget. The size of this budget is based on management experience rather than objective analysis. Mid-asset-life preservation actions can be funded from either the operations or the capital budget, depending on the magnitude of the work. This category of work is under-funded and would benefit from improved planning tools to correctly size the budget, select the best candidates for this activity, and produce a more balanced investment plan. The typical strategy used by MnDOT to develop investment levels for bridges is summarized in Figure 8-11.

For years 2018-2027, MnDOT envisions capital 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 $28 million in maintenance projects, $64 million in preservation projects, $373

Figure 8-11: MnDOT Typical Preventive/Corrective Actions Investment Strategy for Bridges

in rehabilitation projects, and $695 million in reconstruction projects. Figure 8-12 show yearly investment by work type. The percent of bridge deck area on the National Highway System in poor condition increased slightly in 2017. Performance on the NHS expected to decline slightly below the target. 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 two percent of NHS bridge deck area and eight percent of non-NHS bridge deck area should be in poor condition.

Figure 8-12: Yearly Bridge Investment by Work Type



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

HIGHWAY CULVERTS AND DEEP STORMWATER TUNNELS

MnSHIP does not break out the asset categories within the Roadside Infrastructure investment category, but culverts make up the largest portion of this 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 envisions a capital and maintenance expenditure need of $41 million for overhead sign structures to meet the target. An investment need will be determined for high-mast light tower structures based on recent condition data.

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

(Text will be added for final submission)

SIGNALS

(Text will be added for final submission)

LIGHTING

(Text will be added for final submission)

PEDESTRIAN INFRASTRUCTURE

(Text will be added for final submission)

BUILDINGS

(Text will be added for final submission)

ITS

(Text will be added for final submission)

Summary

Figure 8-13 summarizes planned 10-year capital investments (from MnSHIP) to achieve pavement and bridge targets, as well as investments needed (determined through the TAMP planning process) to achieve highway culvert, deep stormwater tunnel, overhead sign structure, high-mast light tower structure, noise wall, signal, lighting, pedestrian infrastructure, building and ITS targets.

Figure 8-13: Targets and Planned or 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	$668 million	TBD
Pavement: Non-Interstate NHS	1.7% poor	≤ 4% poor	$2.1 billion	TBD
Pavement: Non-NHS	4.4% poor	≤ 10% poor	$2.1 billion	TBD
Pavement: Total	N/A	N/A	**$4.9 billion**	TBD
Bridge: NHS	4.7% poor	≤ 2% poor	$695 million	TBD
Bridge: Non-NHS	2.1% poor	≤ 8% poor	$362 million	TBD
Bridge: Total	N/A	N/A	**$1.1 billion**	TBD
Hydraulic Infrastructure: Highway Culverts	15% poor	≤ 10% poor	$254 million	$ 37 million
Hydraulic Infrastructure: Deep Stormwater Tunnels	19% poor	≤ 10% poor	$2 million	$2.5 million
Other Traffic Structures: Overhead Sign Structures	28% poor	≤ 6% poor	$8 million	$33 million
Other Traffic Structures: High-Mast Light Tower Structures	18% poor	≤ 6% poor	TBD	TBD
Other Traffic Structures: Noise Walls	11% poor	≤ 2% poor	$2 million	$57 million
Other Traffic Structures: Traffic Signal Systems	29% poor	≤ 6% poor	$157 million	$49 million
Other Traffic Structures: Lighting	38% poor	≤ 6% poor	$125 million	$19 million
Pedestrian Infrastructure	Varies	Varies	$250 million	$250 million
Buildings	Varies	Varies	$261 million	$132 million
Other Traffic Structures: ITS	Varies	Varies	$41 million	$67 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

In accordance with MAP-21, the TAMP development process will be reviewed by the FHWA and certified as meeting the requirements established by the Secretary of Transportation. The process used to develop and maintain the TAMP 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 (AMPO), 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 (TAMS).

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 9-2 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 9-3 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: Completed Priority Strategies for Mitigating Risks

PRIORITY LEVEL STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE
Address the repairs needed on the existing South I-35W deep stormwater tunnel system	To improve condition of South I-35W deep stormwater tunnel; to alleviate safety concerns and reduce overall percentage of deep stormwater tunnel system in poor and very poor condition (thereby helping MnDOT meet targets)	MnDOT Metro District with assistance from the City of Minneapolis
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)	MnDOT Maintenance – Various Districts
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	MnDOT Bridge Office
Place pressure transducers in deep stormwater tunnels with capacity issues	To place pressure transducers in deep stormwater tunnels that will collect better capacity-specific data such as pressure impact by water volume	MnDOT Metro District

Figure 9-3: Prioritized Strategies for Mitigating Undermanaged Risks

PRIORITY LEVEL 1 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIME FRAME	ESTIMATED COST
Research developing a method to 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	Approximately $5 thousand (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	Approximately $150 thousand (for study)
Track overhead sign structures in a Transportation Asset Management System (TAMS)	To more deliberately and effectively manage these asset categories; to include more assets in TAMS, thereby improving cross-asset trade-off decision-making	MnDOT Office of Transportation. System Management; MnDOT Districts	2-4 years	TBD

PRIORITY LEVEL 2 STRATEGY	PURPOSE(S)	RESPONSIBLE OFFICE	EXPECTED TIME FRAME	ESTIMATED COST
Improve highway culvert management using TAMS	To more deliberately and effectively manage highway culverts utilizing the full functionality of TAMS; to refine the business process and asset management tools (such as decision tree)	MnDOT Bridge Office	1-2 years	TBD
Develop an inventory process for deep stormwater tunnels	To improve regularity of deep stormwater tunnel inspections by adding the tunnel system to the bridge inventory, with inspection frequency tied to reported condition	MnDOT Metro District	1-2 years	TBD

Develop a policy requiring a five-year inspection frequency for overhead sign structures, as well as related inspection training programs and forms	To establish a formal inspection program for overhead sign structures based on MnDOT's best knowledge of structure condition, deterioration rates and inspection needs	MnDOT Maintenance – Various Districts	Currently underway	$150 thousand (staff time)
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 (once it is implemented)	To improve overall system quality and management; to meet newly established and vetted asset targets	MnDOT Maintenance – Various Districts; MnDOT Bridge Office	10 years	TBD

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)

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 various preventative maintenance performed on these structures in varying ages and conditions

Noise Walls

- (Text will be added for final submission)

Signals and Lighting

- (Text will be added for final submission)

Pedestrian Infrastructure

- (Text will be added for final submission)

Buildings

- (Text will be added for final submission)

ITS

- (Text will be added for final submission)

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 our business processes and management practices as more assets are included in the TAMP process:

1. MnDOT has strong pavement and bridge management programs in place that have been used for years to support agency planning and programming activities. However, even with strong programs in place, several business process improvements were identified that will further strengthen the programs. The development of the TAMP also helped justify improvements that were already underway, such as completing bridge management tools to improve predictions of future conditions and formalizing the inspection of overhead sign structures 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.

2. 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.

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

4. Invest 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. 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.

10. 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.

11. 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.